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Royal Horticultural Society

FOUNDED
A.D. 1804.

INCORPORATED
A.D. 1809.

REPORT

OF THE

INTERNATIONAL POTATO CONFERENCE

HELD AT THE

ROYAL HORTICULTURAL SOCIETY'S HALL,
VINCENT SQUARE, LONDON, S.W. 1.

ON THE

16th, 17th and 18th November, 1921.

Edited by

W. R. DYKES, M.A., L.-ès-L.

Secretary.

LONDON:

Printed for the Royal Horticultural Society

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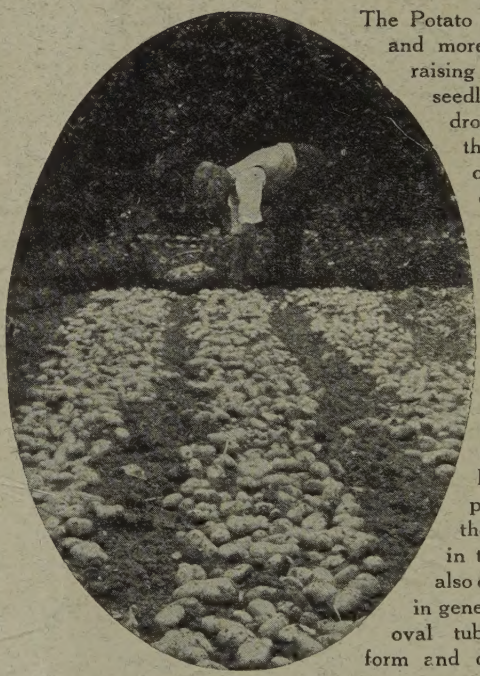

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THE INTERNATIONAL POTATO CONFERENCE

16th, 17th and 18th NOVEMBER, 1921,

AT THE

Royal Horticultural Society's Hall, Vincent Square, London, England.

In order to secure the full discussion of the manifold and complex problems with which breeders and growers of potatos are confronted, the Ministry of Agriculture and Fisheries and the Royal Horticultural Society arranged to hold jointly an International Potato Conference.

Invitations to the Conference were extended by His Majesty's Government to the Governments of the Dominions and Colonies and of Foreign Countries, and the result was a representative gathering of all those interested in the question, whether from the scientific or commercial point of view. Arrangements for the Conference were carried out by a Committee constituted as follows:—

Chairman—Lord Lambourne, C.V.O., Royal Horticultural Society.

Vice-Chairman—Sir Daniel Hall, K.C.B., Ministry of Agriculture.

F. J. Chittenden
W. Cuthbertson
C. G. A. Nix
Martin H. Sutton
} Royal Horticultural Society.

A. D. Cotton
P. G. Dallinger
W. G. Lobjoit
} Ministry of Agriculture.

James Wood, Board of Agriculture for Scotland.

J. R. Campbell, Department of Agriculture, Ireland.

Wilfred Parker, National Institute of Agricultural Botany.

J. R. Poad
W. H. Morter
} National Potato Society.

Joint Secretaries
W. R. Dykes, Royal Horticultural Society.
H. V. Taylor, Ministry of Agriculture.

OFFICIAL DINNER TO THE DELEGATES

On the evening of Tuesday, November 15th, the Foreign Delegates and others connected with the Conference were entertained at dinner on behalf of His Majesty's Government by the First Commissioner of Works, at Lancaster House (London Museum). Lt.-Colonel the Right Hon. Sir Arthur Griffith-Boscawen, M.P., presided to welcome the guests. M. Rolland and Dr. H. M. Quanjer responded on their behalf.

The following accepted invitations to the dinner :—

The Rt. Hon. Edward Mervyn Archdale, Minister of Agriculture for Northern Ireland.
Mr. A. H. Ashbolt, Agent-General for Tasmania.
Professor V. H. Blackman, Imperial College of Science, South Kensington.
Professor Blair, Delegate from Canada.
The Rt. Hon. Lord Bledisloe, Lydney Park, Gloucestershire.
Dr. W. B. Brierley, Rothamsted Experimental Station, Harpenden, Herts.
Mr. J. F. Brooks, School of Botany, Cambridge.
Mr. A. Buchanan, Delegate from Tasmania.
Mr. W. B. Burns, Economic Botanist to H.M. Government, Bombay, India.
Dr. E. J. Butler, Imperial Bureau of Entomology, Kew.
Mr. F. J. Chittenden, Director R.H.S. Gardens, Wisley.
The Hon. Sir James D. Connolly, Agent-General for Western Australia.
Mr. A. D. Cotton, Ministry of Agriculture.
Mr. W. Cuthbertson, Royal Horticultural Society.
Mr. P. G. Dallinger, Ministry of Agriculture.
Mr. J. Conway Davies, Secretary, Government Hospitality Fund.
Mr. J. W. Dennis, M.P., House of Commons, S.W.
M. Ducomet, Professeur à l'Ecole Nationale d'Agriculture de Grignon.
Mr. W. R. Dykes, Secretary, Royal Horticultural Society.
Mr. F. W. Emett, Director, Reuter's News Agency.
Mr. E. M. England, Assistant Secretary, Government Hospitality Fund.
M. Harald Faber, Adviser in Agriculture to the Danish Legation in London.
Prof. J. B. Farmer, Imperial College of Science, South Kensington.
Mr. J. W. Ferguson, Delegate from New South Wales.
Sir Francis Floud, K.C.B., Ministry of Agriculture.
M. Foex, Directeur de la Station de Pathologie végétale de Paris.
M. M. Frangopoulos, Delegate from Greece.
Mr. J. C. F. Fryer, Ministry of Agriculture.
Mr. B. Gerritzen, Government Horticultural Adviser, Maastrict, Holland.
Mr. V. Greae, Delegate from Denmark.

Le Vicomte de Halgouet, Delegate of the Ministry of Commerce, France.
Sir A. Daniel Hall, Ministry of Agriculture.
Mr. J. M. Hannah, Girvan Mains, Girvan, Scotland.
Mr. John Harrison, Jr., President, Horticultural Trades Association.
Mr. F. Hiam, Vice-President, National Potato Society.
Captain Arthur Hill, Royal Horticultural Society.
Sir Henry Hope, Ex-President, Scottish Chamber of Agriculture.
The Hon. J. McEwan Hunter, Agent-General for Queensland.
Dr. Ivar Jerstad, Delegate from Norway.
Prof. F. W. Keeble, Prof. of Botany, Oxford.
Mr. G. S. Kulkarni, Assistant Professor of Mycology to H.M. Government, Bombay, India.
The Rt. Hon. Lord Lambourne, P.C., C.V.O., President, Royal Horticultural Society.
Mr. J. W. Lesley, School of Agriculture, Cambridge.
Mr. W. G. Lobjoit, Ministry of Agriculture.
Mr. G. W. E. Loder, Royal Horticultural Society.
M. Marchal, Directeur de la Station de Phytopathologie de l'Etat à Gembloux, Belgium.
Dr. G. Marshall, Natural History Museum, South Kensington.
Mr. H. B. May, Royal Horticultural Society.
Mr. Donald McKelvie, New Lanark, Lamlash, Isle of Arran.
Sir T. H. Middleton, Development Commission, Board of Agriculture for Scotland.
Mr. A. B. Modak, Delegate from India.
Mr. W. H. Morter, Supt., Parks Department, Birmingham.
Mr. P. A. Murphy, Board of Agriculture for Ireland, Dublin.
Mr. C. G. A. Nix, Royal Horticultural Society.
Mr. F. A. Harman-Oates, Keeper of London Museum, Lancaster House.
Mr. Wilfred Parker, National Institute of Agricultural Botany, Huntingdon Road, Cambridge.
Mr. G. R. Poad, Messrs. Poad and Sons, York.
Mr. Oscar Potier, Consul-General for Portugal in London.
Lt.-Col. Sir David Prain, Director, Royal Botanic Gardens, Kew.
Dr. H. M. Quanjer, School of Agriculture, Wageningen, Holland.
Mr. William Robb, Board of Agriculture for Scotland, Edinburgh.
Mr. R. R. Robbins, President, National Farmers' Union.
Senor Don Leopoldo Hernandez Rolendo, Delegate from Spain.
M. Rolland, Inspecteur Général de l'Agriculture, France.
Sir Albert K. Rollit, Royal Horticultural Society.
Dr. E. J. Russell, Lawes Trust Research Institute, Rothamsted.
Dr. R. N. Salaman, Barley, Royston, Herts.
Mr. E. S. Salmon, Agricultural College, Wye.
Capt. Sir J. Beville Stanier, M.P., Chairman, British Sugar Beet Growers' Society, and Governor, Harper Adams Agricultural College.
Mr. Martin Sutton, Royal Horticultural Society.
Mr. George Swift, President, Fruit and Potato Trades Association.
Mr. H. V. Taylor, Ministry of Agriculture.
Dr. A. Volkart, Head of Swiss Institute for Agricultural Experiments at Oerliken, Switzerland.
Sir Lawrence Weaver, G.B.E., Ministry of Agriculture.
Mr. James Wood, Board of Agriculture for Scotland, Edinburgh.

PROGRAMME OF THE CONFERENCE.

WEDNESDAY, November 16th.

10.30—11.20	Presidential Address. LORD LAMBOURNE, P.C.
11.20—12	Breeding, Selection and Development Work in the U.S.A. WM. STUART, Department of Agriculture, Washington.
12—12.45	Breeding, Selection and Development Work in Britain. F. J. CHITTENDEN, DONALD MCKELVIE and WM. ROBB.
12.45—1.30	Discussion.
3—3.30	The Industrial and Commercial Uses of the Potato. H. V. TAYLOR.
3.30—3.50	Discussion.
3.50—4.20	The Early Potato Industry. I. M. HANNAH.
4.20—4.40	Discussion.
4.40—5.10	Degeneration of Potatos. DR. R. N. SALAMAN.
5.10—5.30	Discussion.

THURSDAY, November 17th.

10—12	Judging of Potato Exhibition.
12 noon	Opening of Potato Exhibition.
2.30—4	Inspection of Potato Exhibition.
4—4.40	Wart Disease of Potatos. V. F. BLACKMAN and WM. B. BRIERLEY.
4.40—5.30	Discussion.
5.30—6	Wart Disease. DR. R. N. SALAMAN and J. W. LESLEY.

FRIDAY, November 18th.

10.30—11	New Work on Potato Blight. G. H. PETHYBRIDGE.
11—11.45	New Work on Leaf-curl in Holland. H. M. QUANJER.
11.45—12.15	New Work on Mosaic in Ireland. P. A. MURPHY.
12.15—12.30	The Situation as regards Leaf-curl and Mosaic in Britain. A. D. COTTON.
12.30—1.30	Discussion.

REPORT

OF THE

INTERNATIONAL POTATO CONFERENCE

1921.

NOVEMBER 16TH TO 18TH,

WEDNESDAY, NOVEMBER 16TH.—10.30 TO 1.30.

THE RT. HON. LORD LAMBOURNE, President of the R.H.S., opened the Conference by extending a most hearty welcome to those who were taking part in the Conference, and especially to the Foreign delegates from France, Belgium and Holland, and to the visitors from various parts of the British Empire. All had come together to add their knowledge to a common stock and to aid one another in solving the many problems which confront the grower of potatos, whether that grower regards the potato as his main crop or merely as a "side-line;" whether he grows many acres or only a few square rods. In proposing a Conference of this nature, the Society had entered upon no new phase of work. One of its first activities more than a hundred years ago was to offer prizes for the development of good new varieties; one of its first series of garden experiments a hundred years ago dealt with the cultivation of potatos; ever since it had, by exhibitions, comparative tests of cropping and cooking, by experiments in methods of cultivation and of dealing with diseases, done all in its power to improve varieties and to spread a knowledge of the best methods of growing them. Science had come to the aid of the practical grower, who was rapidly learning to look to science to suggest improvements in his methods and to aid him in increasing the returns for his labour and expenditure. This Conference would bring to light the latest additions to the knowledge of these subjects, it would inform the grower of the latest results of scientific investigations, it would enable him as well as scientific men to see where we stood and give him the opportunity to improve his methods in the light of that knowledge; and would, he hoped, prepare the way for an extension of knowledge and for further improvements in a most important crop.

He expressed regret that Sir Daniel Hall, who had promised to preside at its deliberations had been unavoidably detained on the Continent and that the delegates from the U.S.A. had not been able to be present.

INAUGURAL ADDRESS.

By Sir Daniel Hall, K.C.B., Chief Scientific Adviser to the Ministry of Agriculture.

The potato crop is of peculiar importance to the world at the present time. The wholesale destruction wrought by the war has fallen with special weight upon agriculture ; all recuperation, all progress, depends upon a cheap and abundant food supply and that supply has been endangered by the great withdrawals of labour from agriculture which have taken place in all countries and by the hinderances which have grown up to the free interchange of commodities among nations.

Under ordinary conditions the potato crop will yield nearly double the amount of real food that we can get from the wheat crop. Again, the opportunity for European farming lies in the more intensive use of the land, since we have little new land on which to spread and the potato crop is far more responsive to intensive cultivation than wheat can ever be. In England our average crops of potatos and wheat are 6 tons and 4 qrs. per acre respectively, but it is possible to-day to find crops of 12 tons of potatos per acre far more commonly than 8 qrs. of wheat. Moreover, and this is a point of some importance, the home producer, whether he is gardener, allotment holder or small holder, can grow potatos and cannot grow wheat. With the greater leisure the working man has obtained in all countries we shall see a continued increase in home production of food and in this movement the potato will play a pre-eminent part.

This Conference is mainly concerned with the improvement of the potato crop in the field and in the garden, and to that end the chief factors in hand to consider are :

(1) the increase of yield of cultivation and manuring ;
(2) the introduction of better cropping varieties ;
(3) the dissemination of good seed ;
(4) the prevention of disease.

Now with the first topic this Conference does not purpose to deal, it is more appropriate to a purely Agricultural Conference and I am not aware that there is any particularly novel point to be brought out at the present time. I should however like to point out that the introduction of the potato crop into a farmer's rotation does make for higher production all round on the farm. It involves deeper and more thorough cultivation and heavier manuring than the other crops of ordinary farming and the effect is seen throughout the rotation. It may safely be said that the distinctively potato farms constitute the best utilised and most productive land in the country. Of course we cannot all at once increase our potato acreage, the market will not stand it, and it is one of the duties of the industry to conduct a propaganda

and enlighten the people on the value of the potato as food and on the many ways in which it can be utilised.

On the importance of the second point—the introduction of improved varieties—all are agreed and much of the time of this Conference will be spent in consideration of many of the questions involved. But I should like to take this occasion of pointing out how large a share Great Britain has taken in this work. It is impossible nowadays to recover the earliest history, but in the first half of last century there were many working men gardeners in the north and midlands of England who substantially contributed to the raising of new varieties which crept slowly into general use, as, for example, the old fluke potato. A little later the chief milestones along the road are the introduction of Victoria by Paterson about 1856, of Magnum Bonum by Clarke of Christ Church in 1876 and of Champion, the first variety showing a distinct resistance to blight, by Barclay in 1878. Later we had Findlay's Up-to-Date and British Queen in 1893 and 1894, a marked step forward, varieties which dominated the country for many years and are still extensively grown. King Edward, introduced by Bullen in 1902, has been the most prominent of recent potatos, while to-day we are chiefly occupied with a consideration of the marvellous range of new varieties that are immune to wart disease. That problem we can take as solved, moreover it points the way to dealing with those other diseases, blight and leaf-curl and mosaic, which are still the chief factors limiting production and increasing the price to the consumer.

In this question of the introduction of new varieties the Ministry of Agriculture is now playing an important part. I need only refer very briefly then to the work of the Synonym Committee which is intended to protect the potato-growing public from the many disappointments they have suffered in the past from the mistaken or even fraudulent putting out of old varieties under a new name. From the Synonym Committee the public now can get a trustworthy opinion as to the authenticity and character of the many new varieties that are yearly being put upon the market.

To turn to the third point in seed potatos, one of the most noteworthy advances of my time in potato growing has been the establishment of the immense value, as regards production, of seed drawn from a colder and moister habitat. I won't say simply Scotch or Irish seed, because I don't believe the potato recognises any principle of nationality, and because I believe we have localities in England and Wales that could be equally effective in producing good seed for the typical potato-areas. We don't know as yet what are the factors in the case, we only know the results empirically, but research has been set on foot on the question and I am hopeful that we may arrive at an answer that will be of value to the potato grower. The heavy freight charges on potatos

that come from any distance make it now a question of much moment to the southern potato grower. Closely allied to this subject is the much disputed question of degeneration. Does a variety age or does it only accumulate the seeds of diseases like curl and mosaic, which do not destroy the crop but only limit its productivity? In the latter case regeneration may be possible, in the former we must accept the gradual wearing out of our most trusted varieties.

In this question of seed potatos perhaps the most important matter for the moment is to secure seed of the stock to be planted free from taint, most notably the taint of wart disease. In this connection the attention of the Conference will be called to the steps the Ministry is taking to secure the purity and freedom from disease not only of the seed potatos in export but also of the stocks that are sold in this country. The United States and Holland are going further and have envisaged leaf-curl and mosaic in their protective measures. I trust that this Conference will throw further light on this important question.

The whole question of disease is of far greater economic importance with regard to potatos than any other crop. The intensive character of its cultivation, the fact that it is continuously carried on by asexual propagation makes it a peculiarly susceptible plant. There are two main methods of dealing with disease, curative or preventive measures, which are exemplified in the spraying with Bordeaux mixture now universally employed to combat Phytophthora, and the more radical method of breeding for immunity which has proved so successful in meeting the incurable wart disease. Without doubt the latter method represents the most promising line of action and though as yet the potato breeders have not been able to give us varieties that will resist blight or leaf-curl, it is not probable that such immunity cannot be attained, to the great economic advantage of the cultivator. Curative measures are always expensive and always liable to failure through errors of judgment or bad handling, even when they are adopted.

Lastly, as the international trade in seed potatos and even in ware is of great importance, I trust this Conference may help to establish a good understanding between the scientific officers of the various countries who have charge of the measures taken to prevent the introduction of disease. Every country has to establish some measure of control of imports lest they bring in new diseases capable of ravaging the national crop. These necessary health regulations are often made the cover for purely protective measures designed really to do away with commercial competition. Any country has a perfect right to establish protection if it desires, but from every point of view we wish to keep the two matters of disease prevention and commercial protection distinct. This cannot be done unless each country has confidence in the measures adopted in other countries to check the

export of diseased stocks and in the capacity and good faith of the technical officers administering such regulations. I have every hope that this Conference will assist in bringing about such a mutual understanding.

The PRESIDENT then called upon Mr. Dykes to read the paper on "Potato Breeding, Selection and Seed Development Work in the United States," sent by Professor Wm. Stuart, who had been unable to come over from America.

POTATO BREEDING, SELECTION AND SEED DEVELOPMENT WORK IN THE UNITED STATES.

By WM. STUART.

To the uninitiated the subject of plant breeding seems to be surrounded with much mystery. This is probably largely due to the fact that the reproductive organs of plants and the functions performed by them are relatively little understood by the average person; but when once familiar with these processes, plant breeding is no more mysterious than animal breeding; in fact, the same general laws of reproduction apply to both.

Breeding and Selection Defined.—Before proceeding further with the discussion of breeding and selection as related to the potato, it seems desirable to briefly define the use and the application of these two terms in this paper. Breeding as here employed refers strictly to sexual reproduction. Selection refers to the isolation of any desirable variation in a variety from that of the normal and its perpetuation by asexual propagation.

Limitations of Breeding and Selection.—Broadly speaking the limitations of potato breeding are those which are found within the confines of the tuber-bearing species of Solanums; but for the most part it may be regarded as being confined to the varieties occurring within the species to which the potato is assumed to belong. The breeder has therefore within his power the possibility of crossing two varieties, each of which may possess certain desirable qualities not possessed by the other, with the view of combining them in some of the resulting offspring.

The improvement of the potato by selection is limited to the natural variations occurring within the individual variety itself. As not all such variations are heritable, one cannot always be certain that the mere selection of a variant means progress until it is thoroughly tested. The selectionist, therefore, has a much narrower field than that of the breeder.

Nineteenth Century Potato Breeding Achievements.—Little if any real progress was made in potato breeding prior to 1850, either in

America or in Europe. From this period on, however, rapid strides were made in the development and improvement of commercial varieties of potatos. During this period the chief consideration in the minds of American potato breeders, with exception of Goodrich, seemed to be that of attractive appearance, table quality, and productiveness. European breeders on the other hand, paid quite as much attention to disease resistance and starch content as to the other factors mentioned.

American Potato Breeders and their Accomplishments.—To attempt an enumeration of all American potato breeders who have had a part in the improvement of the potato during the last half of the nineteenth century is neither feasible nor desirable, but in order to intelligently trace the progress made from the time of Goodrich to that of Carman and others, the following list of names is presented as worthy of mention: Goodrich, Bresee, Brownell, Pringle, Rand, Gleason, Heffron, Burbank, Alexander, Reese, Coy, Carman, Craine, Bovee, Safford, and Van Ornam.

The severe epidemic of late blight that swept over this country and Europe during the years 1843 to 1847 and which reached its climax in Europe in 1845, causing a widespread famine in Ireland, led the Rev. Chauncy Goodrich, of Utica, N.Y., to conceive the idea that the potato as a result of long-continued asexual propagation had become so weakened in vigour as to be no longer able to successfully resist the attack of disease. He believed that it could only be rejuvenated through sexual reproduction and began to make his plans for the growing of seedling potatos with the idea of developing more vigorous and productive varieties that would be able to very largely resist disease. Through the kindness of the American consul at Panama, Goodrich (5), in 1851, received a small quantity of South American potatos for breeding purposes. Among this lot was a variety which, from its rough purple skin and its supposed place of origin, he descriptively named the Rough Purple Chili. From naturally fertilized seed balls of this variety produced in 1852, he grew some seedlings in 1853. Out of this lot one was selected as worthy of propagation. This seedling was introduced in 1857 under the name of Garnet Chili. In speaking of his work, Goodrich says (4): "From the beginning of 1849 to the close of 1854 I originated about 5,400 varieties . . . I have now but 33 sorts left, many of which I shall doubtless reject in a year or two. The 3,000 new sorts originated in 1855 and 1856 promise better, but, even among them the proportion of truly valuable ones will in the end doubtless be small." Goodrich's statements regarding the relatively few desirable seedlings that are likely to be obtained by the plant breeder indicates a careful and conscientious rejection of all inferior plants and a firm resolve not to offer to the trade any unmeritorious varieties. That he had a clear notion of the

problem before him is evidenced by his summation (Loc. Cit. pp. 273-275) of what he considered were the important traits which should be included in a valuable variety of potatos. These are as follows: "1. Good shape; 2. White flesh; 3. Hardiness; 4. Freedom of growth; 5. Resistance of dry weather; 6. Fine flavour; 7. Early maturity." Not only does he mention these attributes of a good variety, but he also indulges in a discussion of varieties having the right shape and those that did not. He further shows his familiarity with the behaviour of varieties by citing those possessing what he terms good bases from which to grow a large proportion of seedlings having shapely tubers. For example, he mentions the Rough Purple Chili as a bad base to use for shape, but a good one for colour of flesh and hardiness.

So far as known, Goodrich did not do any artificial crossing, all of his seedlings being produced from naturally fertilized seed balls. While in this respect he failed to perform the highest type of plant breeding, his work nevertheless impresses one as having been carefully conducted. The varieties that he originated were the Calico, Cuzco, Early Goodrich, Garnet Chili and several others. Of these the Garnet Chili is still being grown in some localities as a commercial variety.

The importance of Goodrich's work lies not so much in what he himself originated, but rather in the varieties produced by others from his Garnet Chili seedling. In a remarkable tribute to Goodrich, Henry Ward Beecher says: (1) "There are few instances on record of zeal so interested, chiefly in two respects: First, in that he would not permit himself to be imposed upon in the judgment which he placed upon the merits of his seedlings; and secondly, in that he worked out his benevolent labours to the end of his life, without turning his industry to his own profit. He was so busy with his experiments that he had no time to make money."

He was a prolific writer and something like 130 articles from his pen were published in the horticultural and agricultural journals and reports of that period. There can be no question as to the tremendous impetus that his work and his writings imparted to those who later followed in his footsteps.

The next important contribution to the list of potato varieties in America was that of the Early Rose. This variety was originated in 1861 by Albert Bresee, of Hubbardton, Vt., from a naturally fertilised seed ball of the Garnet Chili, and was introduced in a limited way in 1867. The Early Rose may be regarded as the first real promising commercial variety produced in America. It may also be regarded as the foundation stock from which emanated many of our present day varieties. Bresee also originated King-of-the-Earlies, Peerless, and Prolific.

Figs. 1 and 2 show reproductions from the original cuts of the

Early Rose and Peerless. The Peerless has the same parentage as that of the Early Rose, both being seedlings from the same seed ball.

The work of C. G. Pringle, of Charlotte, Vermont, will always stand forth in the minds of American potato breeders as representing the first careful effort to cross potato varieties with the object of combining in the resultant offspring certain desirable characters of the parent plant. Pringle was a close observer of nature, a keen student and a good botanist, and he early acquired such skill in the technique of crossing that we find him in the early '70's contracting with a leading seedsman of New York City to produce hybridised potato seed at $1,000 per pound. Considerable seed was produced at this price and through the seedsmen was widely disseminated. There is every reason to believe that Pringle's hybridised seed produced many varieties for which the hybridiser never received the credit. His varietal contributions were the Alpha, Adirondack, Rubicund, Ruby, and Snowflake. The latter variety is still remembered for its high table quality, but on account of a weak habit of growth and comparative unproductiveness it has practically gone out of cultivation, at least in a commercial way. The other varieties mentioned were relatively short-lived. Unfortunately for plant breeding, Pringle abandoned this field of endeavour just when his productive powers were at their zenith, and became a botanical collector and explorer, in which pursuit he was so successful as to earn the title of "Prince of Collectors."

In 1876 Robert Fenn, one of England's famous potato breeders, published under the caption of "Looking Back" (3) some very interesting correspondence between himself and Pringle relative to potato breeding. The following quotation from Pringle's letter, under date of January 5, 1876, indicates how thoroughly imbued he was with the subject of potato breeding. "Twenty years ago there was little disparity, as I suppose, between English and American potatos. The majority of the varieties which we now employ, or certainly those which are grown most extensively, have originated since that time, and have descended from semi-domesticated varieties from South America." "Hybridisation of species has been one of my aims. Besides the original species from the Andes, Solanum tuberosum, I cultivated one, very distinct, from our western territory of New Mexico, S. Fendleri. As yet all my pains taken to impregnate it with pollen of the cultivated species has proved unavailing, though partially developed fruits have followed my operations, only to fall away, however, before maturity. When I learn the conditions which the plant requires, and more fully meet them, I shall succeed, doubtless. . . . Peru can furnish still another species, S. Montanum (vide *Bot. Mag.*), and I am very anxious to secure it."

This glimpse of Pringle's work serves to show the thoroughness

FIG. 1.
From original cut of the Early Rose.

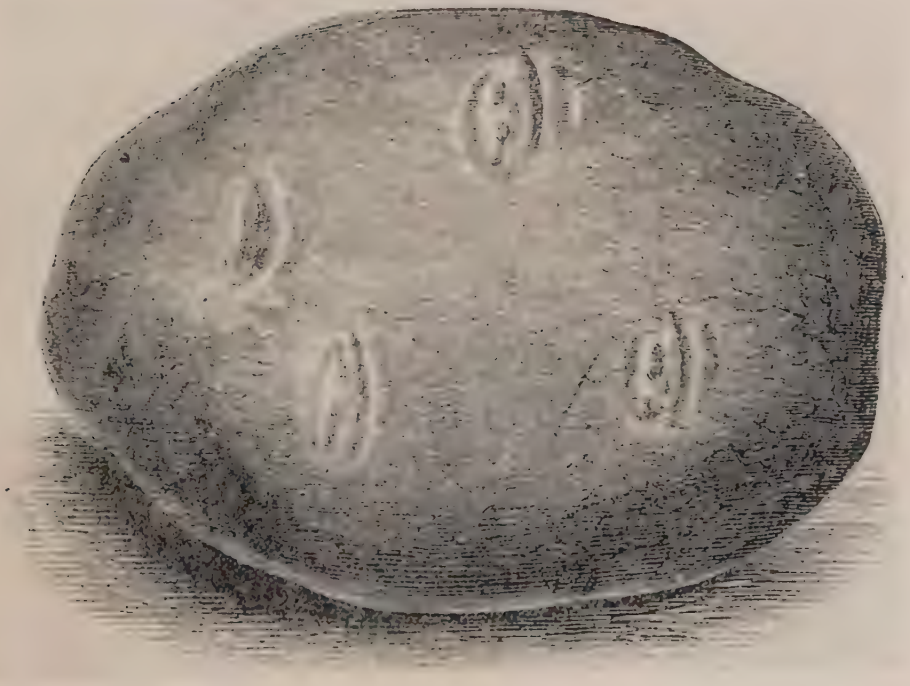

FIG. 2.
From original cut of the Peerless.

[*To face p.* 18.

with which he attacked the potato breeding problems of his day, and one can hardly refrain from indulging in retrospect as to what he might have accomplished had he continued his breeding work.

The work of C. W. Brownell of Essex, Vermont, though not of as high an order as that of Pringle, extended over a somewhat longer period and his introductions are more numerous. The best known varieties are Beauty, Best, Centennial, Early Telephone, Eureka, Superior, Winner and Vermont Beauty (Beauty of Vermont). So far as known Brownell did not make any artificial crosses.

Albert Rand, of Shelburne, and later of Bristol, Vermont, came more nearly following the same line of breeding as that of Pringle. His productions were Champion, Delaware, Matchless, Improved Peachblow, and Silver Skin.

O. H. Alexander, of Charlotte, Vermont, was a seedsman as well as a plant breeder, and it is a little difficult to determine whether some of his introductions were of his own origination or not. So far as known, he did not cross-pollinate potato blossoms. The seedlings that he originated were either grown from naturally fertilised seed balls or from hybridised seed produced by others. His introductions were rather numerous and one of them at least is extensively grown. The list is as follows: Charles Downing, Dakota Red, Everitt, Garfield, Green Mountain, Reliance, Trophy, and White Mountain. Of this list the Green Mountain is by far the most important, and its prototypes are among the most widely grown varieties in the northeastern United States.

The productions of Gleason and Heffron were neither numerous nor important. The former originated the Willard and the latter the Chicago Market and Climax. Heffron was closely associated with Goodrich toward the close of the latter's life and assisted in introducing some of his seedlings.

Luther Burbank's claim to notice in connection with potato breeding work of this period lies in the fact that he was fortunate enough to produce a seedling named after himself, which became widely known and is still extensively grown in some sections, particularly in California. The story of the origin of the Burbank Seedling is not indicative of any particular effort on Burbank's part. It is simply a story of the discovery of a naturally fertilised seed ball on an Early Rose plant in his mother's garden at Lancaster, Massachusetts, its subsequent loss and re-discovery on the ground beneath the plant, the growing of 23 seedling plants from this berry and the selection of the most promising one, which, three years later, 1876, was introduced by Gregory, of Marblehead, Massachusetts, under the name of Burbank's Seedling. Contrast this record with that of Goodrich, who grew about 12,000 seedlings extending over a period of about 15 years and out of all this number failed to produce any that brought him as

much lasting fame as did Burbank's Seedling. This simply serves to illustrate a point too frequently lost sight of by the plant breeder, and that is, that those who follow the pioneer usually reap the richest reward. Bresee produced an Early Rose from Goodrich's Garnet Chili, and Burbank produced his seedling from the Early Rose. In like manner Alfred Reese in 1871 obtained the Early Ohio from a naturally fertilised seed ball of the Early Rose, a variety that is still extensively grown in the Red River Valley, in Minnesota, and North Dakota and in the Kaw Valley in Kansas and many other localities in the Central and Western States.

E. L. Coy. of Hebron, N.Y., obtained the Early Beauty of Hebron in the early '70's from a naturally fertilised seed ball of the Garnet Chili. This variety was introduced in 1878, and for a considerable period was rather extensively grown. It was a heavy producer of fair quality potatos, but both vine and tuber were extremely susceptible to late blight. At the present time it is little cultivated. Coy was also the originator of the following varieties: Late Beauty of Hebron, Early Puritan, Empire State, Late Rose, Noroton Beauty, Thorburn, Vaughan and White Elephant.

Thus within a comparatively few years there was developed from the Garnet Chili and its daughter, the Early Rose, several varieties that are still extensively grown, and from which many others have sprung to enrich our agriculture.

The work of E. S. Carman, former editor of the *Rural New Yorker*, is of extreme interest to the plant breeder, in that he introduced an entirely different strain of seedling potatos into our agriculture. So far as we are able to judge, Carman's varieties do not possess the same blood as do those which have sprung from the Garnet Chili or the Jersey Peachblow. Unfortunately Carman did not keep careful records of his work, and the exact parentage of his seedlings is not known. He admits that he failed to make any crosses between the varieties in his collection, and, according to his own account, even failed in the earlier years of his work to find any naturally fertilised seed balls. This lack of success in securing seeds led him to advertise widely in the *Rural New Yorker* for potato seed balls. In response to this appeal some seed was received from Europe, and from these he produced seedlings that in turn bore seed balls, and from this seed he obtained his Carman No. 1, 2 and 3. On its introduction, Carman No. 2 was given the name of Rural New Yorker No. 2. Sir Walter Raleigh was produced from seed of the Rural New Yorker No. 2. Carman's productions have added millions of dollars to the productive wealth of the States of New York, Michigan, Wisconsin, Iowa and Minnesota, and as yet there seems to be no diminution in their vigour.

Thus far all the potato breeders discussed have been residents of some half-dozen States, all of which except Ohio and New York belong

to the New England group. The chief centres were New York and Vermont. It would hardly be fair, however, to claim that nothing had been attempted in the Middle West in the development of new varieties. Among those who have been most prominently identified with this work might be mentioned the names of Martin Bovee, of Michigan, Thomas Craine, of Wisconsin, and F. B. Van Ornam, of Iowa. Bovee originated Bovee, Early Michigan and Pingree. Craine gave us June Eating, Keeper and Potentate. Van Ornam's contributions were: Extra Early (Burpee's) and Great Divide.

In concluding this enumeration of nineteenth century potato-breeders we do not claim to have mentioned all who are entitled to recognition, nor that the list of varieties given represents all that each of them originated. The object in mind has been rather to give a running history of potato breeding from the middle of the century to its close, in order to show what influence each of the men mentioned may have exerted on the potato industry of the country as a whole, and to bring together in a concrete way such data as would seem to be most important to those who are interested in this subject.

Twentieth Century Progress in Potato Breeding.

In many respects the actual progress made in potato breeding in this country since 1900 falls far short of that made from 1851 to 1890. Convincing evidence of the truth of this assertion may be obtained by a careful perusal of the seed catalogues from 1867-1890. No such activity can be shown in any later period, nor can anything like as good descriptions of the newer introductions be found in our present-day catalogues. This apparent decadence of interest in potato breeding may be practically explained by the fact that during the '90's the extremely low prices of farm products had a depressing effect on the potato industry. Another factor which no doubt served to lessen interest in potato breeding was that with the introduction of the Green Mountain and Rural types of potatos, which are so admirably adapted to the northern and north-eastern sections of the United States, there was little incentive to indulge in this line of effort. Although a number of new varieties have been introduced by American seedsmen since 1900, it can hardly be claimed that much real progress has been made in a commercial way. The only acquisitions that are promising are the russet types of the Burbank and Rural groups of potatos.

It would be misleading, however, to allow the impression to prevail that no real progress had been made in potato breeding since 1900. East's (2) studies on viability of the pollen of American varieties of potatos, and on the relative percentage of successful artificial crosses, on upper, intermediate, and lower flower cymes of individual plants have thrown considerable light upon the question of artificial pollina-

tion. Newman and Leonian (6), in a study of the relation of size and vigour of seedling plants to the production of seed-balls and tubers, concluded that there is no correlation between these characters. They also report that the primary object of their studies is that of developing a strain of the Lookout Mountain potato that will reproduce true to type from seeds as well as from tubers. In 1915 Stuart (8) published an account of studies in potato-breeding and selection covering work begun at the Vermont Station in 1903, and continued with the United States Department of Agriculture from 1909 to 1914 inclusive.

Difficulties involved in Potato Breeding.—One of the chief difficulties confronting the potato breeder is due to the fact that so many of our most desirable commercial varieties bloom very sparingly if at all in some localities. A further hindrance to the work is encountered through the failure of most of the varieties to produce viable pollen in sufficient quantity to impregnate the stigmas and ovaries of the flowers to which it is artificially applied. This statement applies almost equally well to the free blooming as to the shy blooming varieties.

Untoward seasonal conditions at the time the blossom buds are forming may either entirely suppress the development of the buds or they may drop off before the flower expands.

A further obstacle to potato breeding which, for the want of a better term we may call Nature's obstacle, is found in the fact that the majority of varieties producing an ample supply of viable pollen are lacking in one or more of the qualities necessary to commend them as desirable commercial varieties. Owing to these obstacles, therefore, it is difficult to secure a full expression of any given cross in the F2 population.

Of the many American varieties studied by the writer since 1903, only five have been noted which could be regarded as dependable sources from which to obtain viable pollen. These five varieties were Early Silverskin, Irish Seedling, Keeper, McCormick and Round Pinkeye. There are times, however, when it is possible to secure sufficient viable pollen to make artificial crosses with pollen from varieties belonging to the Burbank, Green Mountain and Rural groups, and less frequently from members of the Irish Cobbler, Triumph, Early Michigan, Early Rose, Early Ohio, Beauty of Hebron and Pearl groups. The Peachblow group is omitted because the McCormick and Round Pinkeye, previously mentioned, belong to that group.

The Technique of Potato Breeding.—The technique of potato breeding is too well known to require description. Our only object in mentioning it is for the purpose of giving a brief outline of the method pursued by the writer and his Department associates in making artificial crosses. The process followed is to select the plants

which are to be used as the seed parents, after which the anthers are removed from all flower buds of a suitable stage of development. In general we prefer to select buds that will normally open in from 24 to 48 hours. At this stage the stigma does not usually protrude through the unopened corolla, and is therefore not contaminated with foreign pollen. The emasculated flowers are enclosed in one pound paper bags. Wherever feasible it is desirable to enclose a goodly amount of foliage with the flower cluster. The foliage effectually protects the stigmas of the emasculated flowers from being broken off through contact with the bag when blown about by wind. Pollen is applied to the stigmas of the inclosed flowers in from 24 to 48 hours after emasculation. The operation of pollinating the blossoms is greatly facilitated by first collecting flowers of a suitable stage of maturity (the proper stage is just after the opening of the terminal pores of the anthers) and placing those of each variety to be used in separate and properly labelled individual sacks. The pollen is removed by pushing back the corolla and holding it there with thumb and forefinger of the left hand; then with a pair of fine-pointed tweezers remove the pistil of the flower, after which the anthers are laid over the thumbnail and the pollen jarred out on it by means of tapping the anthers sharply with the tweezers. When a sufficient amount has been collected remove the sack and apply the pollen to the stigma of the prepared flowers. After carefully recording the cross and affixing a numbered string tag to the pedicel of the flower cluster, replace the bag over the flowers and let it remain over them for a week or ten days. At the expiration of this period the sack should be removed and the resultant success or failure noted. If the cross has been accomplished the developing fruits should be inclosed in a cheese cloth sack and firmly tied to the stem of the plant in order to protect them from being knocked off by wind or other causes. The seed-balls are allowed to remain on the plants until ripe or until killing frosts are likely to occur, when they should be removed and allowed to fully ripen indoors.

Since 1910 the U.S. Department of Agriculture has, with two exceptions, grown several thousand potato seedlings each year. The largest number grown in any one season was in 1910, when over 28,000 potted seedling plants were transplanted into the open field in the vicinity of Washington. At the present time our policy is to grow from 5,000 to 7,000 new seedlings each year.

As the object of the potato breeding work of the Department is the production of varieties more resistant to disease than the commercial varieties now in use, the success which has thus far attended our efforts has been rather meagre. While it is true that many seedlings have been produced that have shown marked resistance to the late blight (Phytophthora infestans) these have, almost without exception,

been lacking in some important requirement of a strictly first-class commercial variety. Late blight resistance seems to be associated with one or more of the following undesirable characters : late maturity, large vine growth, poor yielding capacity, rough unshapely tubers, deep eyes, coloured skins, etc. Immunity or rather resistance to late blight was the first object sought after by the Department investigators. The first serious step taken consisted in a preliminary survey of blight resistant European varieties in 1904 by a Department representative. As a result of this survey a considerable number of disease resistant European varieties were secured for study as to their blight resistant qualities and their possible use as parent stocks in the production of new varieties. As a rule most of these imported varieties proved to be undesirable parent stocks. Our present efforts are confined quite largely to varieties of American origin, or to be more specific, to our leading commercial varieties. During the past few years the scope of the work has been enlarged so as to include a study of immunity to all transmissible diseases of the potato.

Prior to our certain knowledge of the communicability of mosaic, and of leaf-roll diseases, those engaged in potato breeding work have had the result of their efforts vitiated, and in most cases lost, through mosaic or leaf-roll infection of the most promising seedlings.

While the Department has not as yet introduced any highly disease-resistant meritorious commercial variety, there are a number of seemingly promising seedlings that are being closely studied, and it is confidently hoped that in the near future we may have some.

Potato Improvement by Selection.—However interesting we may regard the subject of potato-breeding it is realised that but few growers have the time or the skill or the financial means necessary to engage in it. In the improvement of the potato by selective methods alone, the selectionist is limited to the natural or accidental or discontinuous variations within the variety itself. Naturally, therefore, selection processes are less involved than in the crossing of plants and the raising of seedlings.

Selection Methods.

Broadly speaking, there are three general methods of procedure which the selectionist may pursue in the isolation of desirable strains of potatos. These three are known as the tuber-unit, hill and mass selection methods.

Tuber-Unit Method.—This method consists in the selection of desirable shaped tubers of from 6 to 8 ounces in weight from the potato bin. These selected tubers are quartered lengthwise and planted consecutively in the row, leaving a blank space between the four seed pieces of each tuber. The best appearing and most uniform four-plant units are marked during the growing season, and when

harvested the progeny of each unit is carefully studied for yield, and uniformity of size, shape and colour of tubers, and the best of them retained. The tubers from each unit are kept separately and planted in progeny rows or plots next season.

Hill Selection Method.—In the hill selection method the most promising looking plants in the field are marked during the growing season and are dug separately and judged by the same standards as are those from the tuber-units.

Mass Selection. —The mass selection method differs from the hill selection method in but one respect, and that is that the tubers from the selected plants instead of being kept separately are all thrown together and are planted in the seed plot the following season.

A careful study of the literature on potato selection studies furnishes rather convincing evidence that the greatest value to be derived from the practice of selecting seed from the most desirable plants is that of the elimination of weak and diseased plants. Viewed in the light of our present-day knowledge of the mosaic and leaf-roll diseases of the potato, it seems evident that a wrong interpretation as to the actual reason for unproductiveness in some plants and productiveness in others has often been made. In most cases it has been assumed that the productive plants were superior strains which could easily be isolated by selective methods. It now seems probable that many so-called superior strains were simply normal healthy plants, and that the less productive ones were affected by disease which lessened their vigour. Parisot (7) apparently recognised this fact, as he distinctly states that if no account is taken of a perfectly healthy condition of the seed, the yield from normal tubers would be nearly double that from inferior seed.

As a result of nearly twenty years' experience in potato seed selection work, the writer is inclined to believe that but few real valuable variations ordinarily occur within a commercial variety. It is not my wish, however, to appear to discredit potato selection work; it has its place in eliminating undesirable plants, and does occasionally yield something of real worth-while value to the experimentor.

Seed Potato Development Work.—The term seed potato development work has been applied to a line of investigation dealing with a comparative study of different strains of seed potatos procured from different growers with a view to determining the most productive lots of seeds.

This study has proved to be exceedingly interesting and has demonstrated that there are surprisingly large differences in the yield secured from the various growers. The purpose of such work is to find out who has the most productive strain, after which it is increased and

disseminated among interested growers of seed potatos. Although this line of study was not seriously undertaken by the Department of Agriculture until 1919, it has resulted in the recommendation of a superior strain of the Triumph potato which the present year (1921) was grown by 110 Wisconsin growers. While it is not claimed that this line of study is a new one, it is, nevertheless, believed to have greater possibilities for the immediate improvement of the seed stock of a given region than has the individual tuber or hill selection method. The real advantage of such work is to place the best available seed stock in the hands of interested growers, and it also directs the selectionist's attention to the greater possibility of success when working with a good strain. In fact, I am fully convinced of the folly of attempting to very materially improve a poor strain through selective methods. Is it not much wiser and saner to begin with the best available material?

For this reason, if for no other, the type of development work under discussion should be regarded as a necessary preliminary step to all systematic efforts put forth in the development of high-yielding strains of potatos.

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At this point the chair was taken by Mr. W. Cuthbertson, J.P., V.M.H., who called upon Mr. Wm. Robb to read his paper.

BREEDING, SELECTION AND DEVELOPMENT WORK IN BRITAIN.

By William Robb.

POTATOS

Their Breeding, Selection, and Development in Britain.

In response to the invitation to read a short paper at this Conference on "Breeding, Selection, and Development Work in Britain," I have pleasure in contributing a few remarks, and I propose to base them on the work carried out for a number of years by the late Dr. J. H. Wilson, of St. Andrew's University, Scotland, in raising new varieties of commercial types of potatos. I was privileged to assist Dr. Wilson in his experimental work for a few years, and I shall endeavour to outline some of his experiments and to set forth the results he achieved.

Dr. Wilson's Work.

The well-known varieties of Potatos—"Templar" and "Bishop" —were amongst his earliest successes as a Potato Breeder, and amongst the later ones there might be mentioned "Crusader," which according to reports (September) is promising very well in various districts this season. The whole of his stocks of potatos have been taken over by the Scottish Society for Research in Plant Breeding, and they are being further tested at the Society's experimental grounds near Edinburgh. The main object of Dr. Wilson's work was to produce early ripening and later ripening varieties of potatos of high cropping power, highly resistant to, or if possible immune from blight (phytophthora), immune from wart disease, and at the same time satisfying the popular demands as regards shape, colour (external and internal) and standards of quality.

Deterioration of Potatos.

From records written by commentators at different periods it would appear that a potato variety may have had a vogue for a greater or lesser number of years, but that after having been propagated for a time, it deteriorated and ultimately passed out of cultivation altogether. As a result of well-known experiments in various countries, it has been shown that deterioration may be avoided or at least deferred by adopting a rigorous system of selecting seed tubers each season. Under the methods of cultivation still practised, however, deterioration of varieties undoubtedly takes place. This deterioration inevitably creates a demand for either new and vigorous varieties or selected and vigorous strains of those varieties

already in cultivation to take the place of those that are declining in vigour. The breeder of potatos must, like the producer of any other commodity, study to a large extent the demands of the market. To meet these demands he is faced with the problem, amongst others, of effecting the combination of two characteristics which in large measure may be rather difficult to combine—large cropping capacity and a high standard of table quality. In general the primary qualification of the later ripening varieties is that they should produce large crops, and as additional qualifications that they should be of good quality, the tubers should have shallow eyes, be resistant to blight, easy to harvest and come to maturity before the period when there is a possibility of frost damaging the crop.

Dr. Wilson held the opinion that these objects might be most readily achieved by the crossing of selected plants followed by selection from the progeny of the crosses. As parents he used plants of similar types, plants of diverse types and also plants from other species of Solanums, such as S. maglia, S. etuberosum, S. Commersonii. He endeavoured repeatedly to obtain crosses from S. polyadenium, but without success.

Growing of Seedling Potatos.

The practice was to sow the potato seeds in shallow bowls under glass in the month of February and to transplant the seedlings when they were about 2 inches high. In the further growing of the seedlings one method was to grow them individually in pots, repotting them at short intervals as became necessary during a period of about two months. Another method was to grow the seedlings in rows in shallow boxes, transplanting them to other boxes when they were about 6 inches high. In both methods the plants were considered ready for planting out in the experimental grounds by the time they were about 10 to 14 inches high, and generally planting out did not take place before the beginning of June. Immediately prior to transplanting, any excessively stoloniferous or weak plants and many plants bearing coloured tubers were eliminated. Although the roots of the plants transplanted from the boxes were, unavoidably, a little more mutilated than those on the plants planted out from pots, this difference did not have any injurious effects. The selected seedling plants were grown in drills or rows, the drills 2 feet wide and the plants 2 feet apart in the drill.

By growing the seedlings for a period under glass it was possible to obtain well developed plants at the end of the season having foliage as large as that of many of the mature maincrop varieties; the tubers attained a good size and yields up to 3 lb. from single plants were of common occurrence; 6 lb. 4 oz. is the highest yield of tubers from a seedling recorded by Dr. Wilson. In growing

the seedlings in pots it was observed that some seedling plants bore tubers much earlier than others, and it was thought that this early tuber-bearing characteristic in the seedling might be an indication of earliness of ripening or of the tuber-bearing capability of a plant when it reached maturity. Unfortunately, however, this line of investigation had to be abandoned in 1916 owing to the scarcity of labour then prevailing, before any definite conclusions had been reached.

Selection of Seedlings.

In any Plant Breeding work a very essential part is the ruthless discarding of all second-rate and inferior types of plants. While many of the most inferior types will be eliminated at an early stage, it is frequently difficult to distinguish between the first-rate and second-rate material until both have been grown for a few years. It is very probable that the accumulation of second-rate plants often handicaps the efforts of breeders. In the last few years an endeavour has been made to apply as many determinable standards of measurement as possible in the experiments and to rely less on general descriptions. While these enable more reliable comparisons to be made it must be noted that they cannot entirely eliminate the personal factor which will always play an important part in the success or otherwise of plant-breeding work. To discard freely all plants that seem of no economic value is no easy matter; there is always the temptation to follow what might be termed side lines, that is to say for the practical breeder, which he is better advised to leave in the hands of experts working in the field of pure science.

In selecting the stocks for propagation from amongst the seedlings the chief characteristics taken into consideration were, the habit of growth of the plant; the size, shape and total yield of tubers; the depth and number of eyes; the external and internal colour of the tubers; and the presence or absence of blight. The opinion was held that the tubers attained a sufficiently large size in the seedling year to indicate the shape of the tubers in the progeny in future years.

The shape of tubers favoured for selection in the St. Andrew's experiments were the flat round, the flat oval and the kidney. If other characteristics were equal, tubers with shallow and not too many eyes were preferred. Shallow eyes are much favoured for table purposes, but in the shallow-eyed tuber the young sprouts have very little protection and consequently for seed purposes they are likely to be more easily damaged. It is thought this condition may account to some extent for the occurrence of the blanks seen in the drills in some varieties of potatos.

As there is practically no demand for a potato having a coloured skin, many of the seedling plants having coloured tubers were dis-

carded on that account. The difficulty in detecting diseased tubers in a coloured variety creates perhaps a greater dislike to a coloured tuber than is justified. The preference by consumers in this country for a white-fleshed potato renders tubers having coloured flesh of less value and consequently tubers with coloured flesh were more readily discarded. In some seedlings the tubers were badly attacked by blight (phytophthora), and generally speaking all seedling plants having tubers affected with blight were rejected. If a large number of tubers in a seedling plant were attacked by blight, it almost invariably followed that the progeny of the sound tubers from such a plant were also susceptible to the attack of that disease.

The seedling plants were grown in soil as uniform in condition as possible, but as expected there were great differences in the sizes and in the yields of tubers. A few plants produced a large number of small tubers, other plants a small number of fairly large tubers, while others again showed a series of gradations between the two extremes. The results tend to show that a seedling producing a large crop of approximate ware size of tubers gave rise to a variety having high yielding capacity.

Trials and Selections of the Progeny of the Seedlings.

These trials were carried out under ordinary methods of field cultivation and, as with the seedlings, precautions were taken to insure that the conditions of soil and manuring were as uniform as possible. The plants were grown in drills of the customary width, but the tubers were planted wider apart in the drill than usual, the distance apart being 20 inches. This system of wider planting was followed to allow of the crop of tubers from each individual plant being harvested separately. The practice followed at St. Andrews was to plant as whole sets all the tubers of over one inch in diameter from the selected seedlings. Instead of describing the characteristics considered as indicative of a variety which should be propagated still further, it might be convenient to indicate the types which were most frequently discarded, viz., those producing many small tubers or a small crop of tubers, those having a profusion of weak thin stems, those having long stolons, and those attacked by blight. In order to find out if it was possible to grade up or to improve a variety by selecting individually only the best tuber-bearing plants, a large number of individual plants of various varieties was selected annually for a number of years. The stock of tubers from each selected plant was planted separately, but generally alongside of the " mass selection " of its own variety for comparison. In no instance is there any record of a variety having been improved either as regards cropping power or shape by selecting only the best plants or what has been called the plus fluctuations. On the other hand, the vigour of a number of varieties seems to have been

maintained very probably as a result of eliminating many plants affected by leaf-roll or mosaic disease.

As already stated, an important object kept in view by Dr. Wilson was immunity from, or resistance to, blight. While the late ripening varieties of potatos are in general less susceptible to blight than are many of the earlier-ripening varieties, none, so far as is known, are immune. Two varieties raised at St. Andrews a few years ago promise well as regards resistance to blight. Both these varieties are derivatives of crosses of varieties of S. tuberosum with other tuber-bearing species of the same genus, and the pedigree of one of them (No. 800) is appended in full (see page 34). In 1920 blight was very prevalent, and in one of these varieties only 12 tubers out of 2,423 tubers were suspected of having been attacked by blight. In the other variety which has been grown for three years and recorded as having been free from blight, of 128 tubers produced last season there was not one tuber either at the lifting period in October or at the planting time in April this year that showed any trace of blight or disease of any kind. The tubers in this variety are numerous and rather small; they are round, have rather deep eyes, and the skin has a pink flush. Probably in its present state this variety, apart from its resistance to blight, would not be much favoured by agriculturists. But if a variety immune from blight has been evolved, even although it is late in ripening, a very desirable object will have been achieved.

"Sporting" of the Potato.

It would not seem that there are many opportunities of obtaining new varieties from "bud sports." It is very probable that in many instances rogues occurring in varieties of potatos were erroneously supposed to be "sports" and were given new names. Dr. Wilson records after having raised many thousands of seedling potatos that he has observed amongst these only two examples of "sporting." One of the "sports" occurred on a variety which had white tubers and was the progeny of a cross with "Edzell Blue" and an unnamed variety of Dr. Wilson's own raising. It may be of interest to refer briefly to the origin of this "sport." In 1917, when Dr. Wilson's experimental varieties of potatos were being lifted (each plant as usual being dug separately), amongst the tubers of one of the plants of the "Edzell Blue" cross there occurred one tuber only which had a purple-coloured skin. Dr. Wilson saw the plants being lifted, and he has recorded in his notes that there was much reason to assume that this was a genuine case of "sporting." The tubers derived from the "sport" have a deep purple-coloured skin somewhat like that of "Edzell Blue," but they are similar in shape to those of the variety from which they were evolved. The foliage of the "sport" is rather more abundant, and the stems show a much greater development of purple colour. There

would also seem to be differences regarding susceptibility to blight. In 1918, when blight was very prevalent, the tubers of the "sport" were much less affected with disease than the white tubers from the same original. The amounts of blight found on the two varieties last year (1920) confirm the results recorded in 1918.

Development Work.

The basis of potato breeding work generally has been to raise as many seedlings as possible from self-set berries or from berries from known crosses, and to choose for further trial all the most promising seedlings. The greater the number of seedlings that could be raised each season, the greater were the possibilities of success. The wide range of variation which sometimes occurs in the seedlings grown from a single potato berry rendered the delightful possibility of "something turning up" all the more probable. That some very good varieties have been raised on this "hit or miss" principle is recognised, but it must be noted that by this method very little information has been obtained to guide breeders in further prosecuting potato breeding work. It would appear that, if progress is to be made in improving potatos, it is essential that a fuller knowledge of the principles that underlie the work should be obtained.

Probably all the potato varieties at present on the market are genetically impure. It is possible that there may be some "pure lines" of potatos; but if there are any, very little seems to be generally known of them. The intercrossing of these impure types is not providing material which would form the best basis for further investigation of the essentials underlying many of the objects desired to be attained in potato breeding. The evolution of a few potato varieties which for all practical purposes would breed true to type through the seed (berry) seems to be a necessary preliminary to the solution of many problems confronting breeders.

Diseases.

It would be difficult to exaggerate what the consequences would have been had none of the cultivated varieties of potatos been immune from that most destructive disease known as Wart. Unfortunately some of the varieties which are largely grown are not immune from wart disease, and the continued cultivation of these susceptible varieties in infected areas only serves to propagate the disease. The eradication of this parasite is desirable, and could probably be accomplished if only immune varieties were grown. With the facilities provided by the Ministry of Agriculture and by the Board of Agriculture for Scotland for having potatos tested for immunity from wart disease, there should now be no necessity for the multiplication of any new variety until it has been tested for immunity. In general,

varieties that are susceptible to wart disease should not be multiplied.

Within the last few years that premature withering of the potato haulms often referred to as " Rust " has been the cause of diminishing potato yields in various parts of the country. Some potato varieties seem to be more susceptible to this malady than others. Very little seems to be known regarding the cause of potato plants assuming this " rusty " appearance, but there are some indications that it may be due to abnormal soil conditions.

As a result of researches carried out lately by various workers more is now known regarding the diseases " Leaf-roll " and " Mosaic " which attack the potato. In Scotland very little attention has been paid in the past by growers to these diseases, probably because they have been less prevalent in Scotland than in England and some other countries, and their effects in preventing the production of a full yield of tubers have been less marked. Experimenters have demonstrated that " Leaf-roll " and " Mosaic " can be rendered less prevalent in a crop if the seed tubers producing that crop are selected from plants which are free from these diseases. Systematic selection of seed tubers is not largely practised, but it should be more extensively taken up in future by growers, particularly in Scotland, where there is a large demand for seed potatos for the English market.

Early Ripening Potatos.

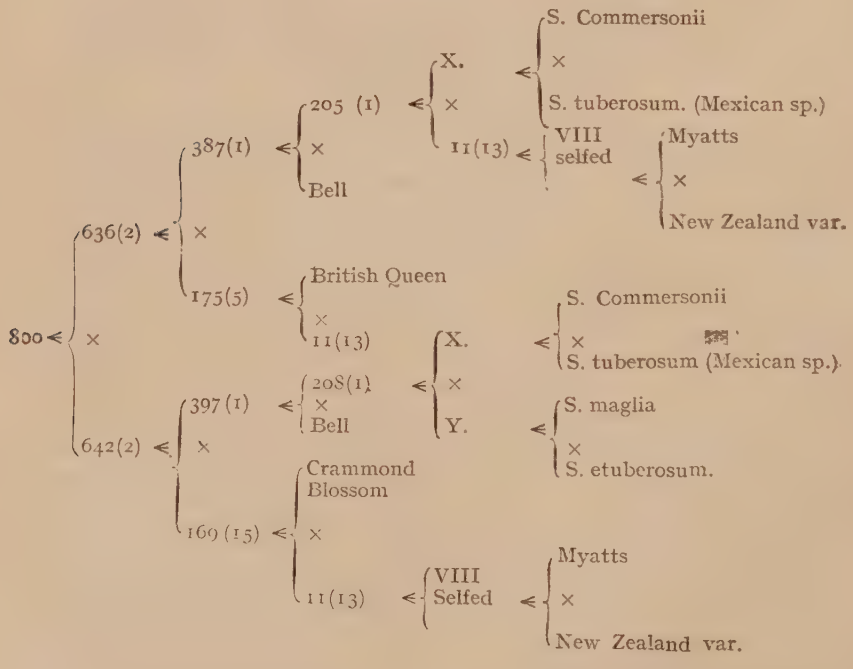
In comparatively recent years an important development of the potato-growing industry has been the growing of very early-ripening varieties. These early-ripening varieties are generally lifted before the crop of tubers is fully developed, and consequently the highest yield is not obtained. It must be recognised that there is a demand by the public for unripe potatos early in the season, but the opinion is held that that demand is stimulated in varying degrees by the poor table quality of many of the late-ripening varieties from the previous season's crop. The call for increased production is imperative, and consideration of the problem of meeting this demand for very early-ripening varieties seems to suggest two possible methods of solution. One is to evolve improved early-ripening varieties, the other is to evolve improved late-ripening varieties which would keep during storage in good condition for cooking for a longer period than is common at present. If the late varieties remained in good condition for cooking until well on in the summer of the year following that in which they were grown, a part at least of this demand for very early-ripening potatos would be diminished.

Quality.

A measure of the importance of table quality in potatos is reflected by a comparison of the relative prices of different varieties in seasons

when the crops are abundant. Some of the varieties which are held to be of the best table quality do not produce large crops ; but although the crop may be smaller, the enhanced price received more than compensates in some seasons for the loss in quantity. In the raising of potatos a high standard of quality has always ranked as an important object, and it seems desirable that as much if not more attention should be paid to this object in future. Different varieties vary considerably in their culinary qualities even when they are grown under the same conditions of soil and climate, and chemical analysis shows that there is a fairly wide range of variation in starch content amongst potato varieties. It would be most instructive to know if there is any correlation between a high standard of table quality and high nutritive content. Investigations might be undertaken in co-operation with Bio-Chemists to determine if any such correlationship exists.

The importance of the potato, both as a foodstuff and as a possible source of fuel, makes it imperative that no efforts should be spared to improve still further a plant which is one of our most efficient transformers of solar energy.



The CHAIRMAN said he thought it would be well to have other papers dealing with this subject before calling for discussion, and therefore immediately called upon Mr. Donald McKelvie for his paper on "Bud Variation in Potatos."

FIG 1.
Arran Victory type, deep purple.

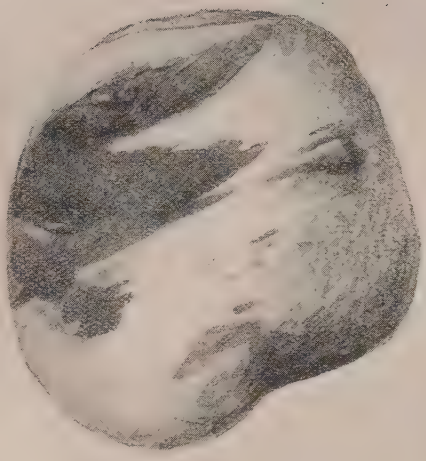


FIG. 2
Arran Victory, partially coloured.

FIG. 3.
Arran Victory, pink with purple eyes and heel.

FIG. 4.
White variation from Arran Victory.

[*To face p.* 35

"BUD VARIATION."

By Donald MacKelvie.

It is generally accepted that new and distinct varieties of potatos can only be produced by sexual propagation.

Mr. Arthur W. Sutton, in a very able and interesting paper read at Ormskirk in 1918, entitled: "Do Potatos give rise to New and Distinct Varieties by Bud-Variation?" was very sceptical about different cases of bud-variation in potatos. The only instances of this kind of sporting he accepts are changes in the colour of the skin of the tubers. He does not regard such a change in colour as constituting a new and distinct variety, nor does the author of a paper published recently by the Board of Agriculture for Scotland, entitled: "The Maintenance of Pure Stocks of Immune Varieties of the Potato." I myself fully share this point of view, and any varieties of potatos that I have produced have been the result of fertilisation—natural or otherwise.

I have, therefore, been very much interested in observing variations developing in "Arran Victory" within the last two years, constituting more than a mere change in the colour of the skin of the tuber, by a process which appears to me to be bud-variation.

As these variations may be of interest to the Conference I shall attempt to describe them. My attention was for the first time drawn to the subject by the discovery in the 1919 crop of a tuber of "Arran Victory" of the usual purple colour over one half its surface lengthwise; the other half was free from any colour. A similar instance, taken from the variety "Princess Royal," is given by the late Mr. John Snell in the "Report of the Ormskirk Trials of 1918." (Supp. to the Journal of the Board of Agriculture, March 1919).

"Arran Victory" was raised in 1911 from a natural plum taken from a white seedling of the "Sutton's Abundance" type. Its tubers are round, with purple skin, white flesh and purple sprouts; its haulm is upright, strong, reddish coloured in the axils and midribs; the leaves are open, dark green and rather glossy; the terminal leaflets are drooping and sometimes tied; the flowers are of a creamy white and do not usually produce plums unless cross-fertilised.

This variety is immune to Wart Disease, and though it was bred from a parent plant very susceptible to Phytophthora infestans, it is largely resistant to the attacks of that fungus.

The abnormal coloured tuber (Fig. 2) which was found in a pit of "Arran Victory" in 1919, was the first deviation I had ever found in this variety. Its appearance aroused my interest, and, looking for

other cases, I soon found in another lot of "Arran Victory" a second abnormality—a tuber (Fig. 3) of a pale pink with dark purple eyes and heel end, and purple sprout. A third case was afforded by the discovery of an oval white tuber (Fig. 4) with a spot of purple at base of sprout at the rose end, and a purple spot at the base end; this tuber had a dark red or purple sprout.

I found other similar variations, but as it would be too complicated to follow them all out here, I shall confine myself to the endeavour to describe the history of each of these three cases during 1920 and 1921.

No. 1.—The tuber, half purple, half white (Fig. 2), with purple sprout, was planted whole in 1920, and, as was also the case with the others, was given plenty of room to avoid intermingling with the roots of other plants. It produced a plant which showed in its foliage all the characteristics of "Arran Victory." I harvested from it 36 purple tubers of the type of "Arran Victory," and five very small white tubers with purple eyes at the rose end and a purple spot at the base end. In 1921 the 36 purple tubers again produced plants and tubers which were not distinguishable from "Arran Victory"; the five parti-coloured tubers all produced plants of the type of "Arran Victory" with parti-coloured tubers. The flesh of these tubers seems to be a little more yellow than that of the tubers of the "Arran Victory" type.

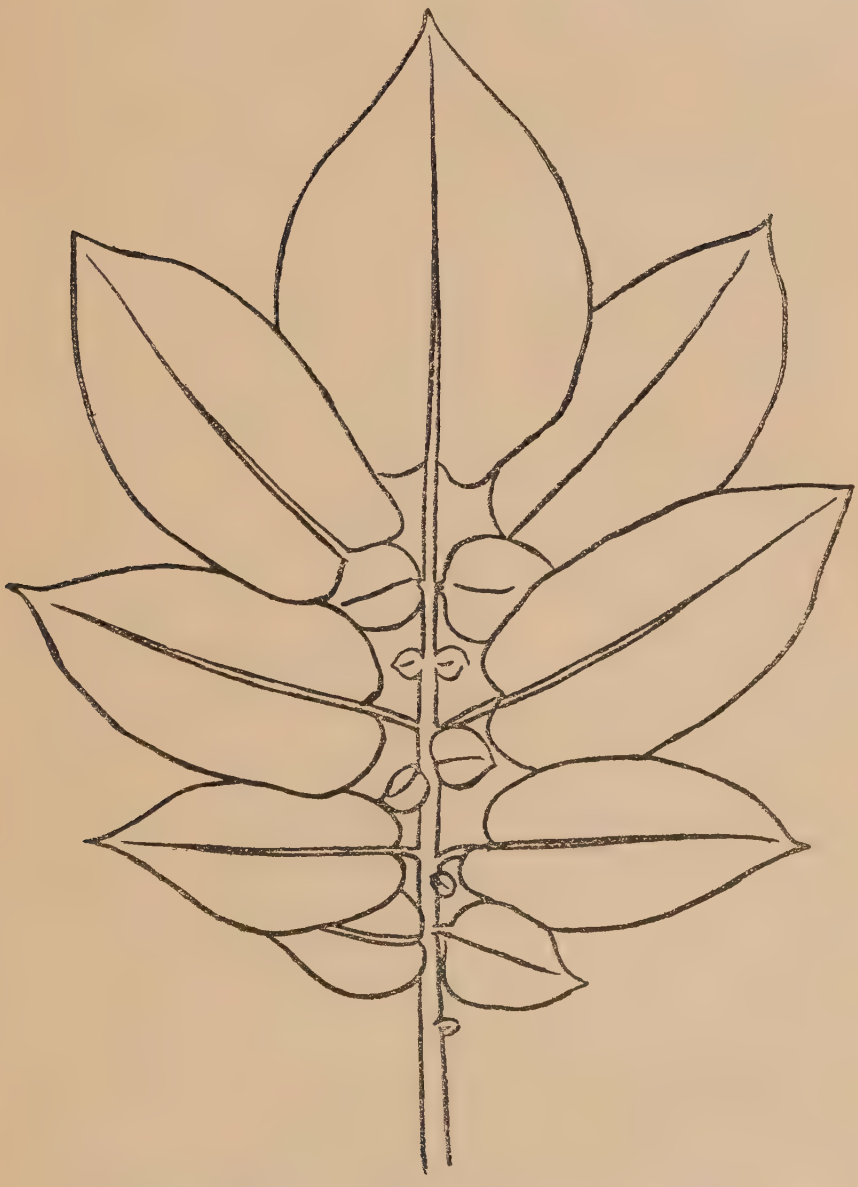
No. 2.—The tuber with the pale pink skin (Fig. 3) and dark purple eyes and heel end, produced in 1920 a plant of the type of "Arran Victory"; its tubers again were of a pale pink, with dark purple eyes and heel end and those planted in 1921 continued to show the "Victory" type in their haulms and the same abnormal colour of the tubers.

Thus far there is no reason to leave the standpoint adhered to by Mr. Sutton and others, that bud-variations are limited to differences in the colour of the skin of the tubers; but the history of No. 3 carries us a stage further.

No. 3.—A white oval (Fig. 4) with spot of purple at base of sprout at rose end, and a spot of purple at the heel end, and dark red or purple sprout. This tuber planted whole produced in 1920 a haulm which I observed carefully during the growing season, and noted as identical with "Arran Victory." This plant yielded five white tubers with purple eyes and purple spot at root end and nine entirely white tubers.

In the spring of 1921 I was surprised to find that while the sprouts of the five parti-coloured tubers were purple, as is characteristic of "Arran Victory," the sprouts of the nine white tubers were pink at the base, with green points and quite distinct.

The five partially coloured tubers produced plants of the ordinary



LEAF OF WHITE VARIATION FROM ARRAN VICTORY.

ARRAN VICTORY TYPE.

⅔ Natural size

type of "Arran Victory" and the tubers retained their original character.

As was to be expected from the change in the colour of the sprouts the plants from the white tubers showed a considerable departure from the original type. The haulms of the nine plants were alike in character. The plants were upright but not so tall as those of "Arran Victory" grown close at hand. The leaflets seemed to be longer and narrower, not coming to a point so quickly, and were more open; their colour was a distinctly lighter green, their surface more glossy, and some of the upper leaflets were a little folded as in the case of primary leaf roll. The terminal leaflet was occasionally tied with one of the lateral leaflets, as is frequently the case in "Arran Victory"; the stem and midribs were entirely free from the red tinge characteristic of the foliage of "Arran Victory," and the whole effect was one of pure, bright, glossy green. The flowers had the same creamy colour, but they seemed to be a little larger.

The tubers from the nine plants showed further variation. In the case of five of the plants the tubers were all white and varied in shape from oval to round. The remaining four plants produced rounder tubers, most of them white, but at each root four or five of the tubers were marked by a few small purple spots; the eyes and heel end were entirely free from colour, and the tuber at the point of the purple spots was usually slightly hollowed, as if the colour was due to injury. The tubers showed a faint ring of purple in the flesh; this is common to all the variations described and also to "Arran Victory."

The plant I have endeavoured to describe is a remarkable case of a type resembling "Arran Victory" closely enough to show its relation, but differing sufficiently to be considered by anyone not acquainted with its origin as a new and distinct variety. It may be claimed, and I quite agree, that the absence of colour in the tuber, and in the stem and midribs, and the change of colour of the sprout, is only colour variation, but it appears to me that these changes, taken in conjunction with the change in the shape of the leaflets, constitute a new and distinct variety if they prove to be permanent.

In concluding this paper I wish to ask the question: "Have any authenticated cases been reported of new and distinct varieties of potatos arising by bud-variation?" It seems from the answers already given by Mr. Sutton, and by the Board of Agriculture for Scotland, that no cases have been observed in this country; but Dr. H. M. Quanjer has kindly supplied me with the particulars of a case described in Holland by Mr. A. van Luyk, and as it is one of great interest, I quote it here.

Dr. Quanjer, writes: — "I take pleasure in giving you some details of the case of bud-variation found by Mr. A. van Luyk, in Holland, in our variety 'Zeeland Blue,' which has round violet tubers and is

very subject to mosaic. A 'Zeeland Blue' potato plant being mosaic in 1911 gave in 1912 all mosaic plants but one, which last one was not mosaic; it had a stronger stalk, broader and smoother leaves and a bigger crop of potatos, which were not round and violet, but somewhat long and dark violet. This plant in 1913 gave rise to several plants, presenting four types. One type had round white tubers. One type had the strong healthy appearance and the dark violet tubers described above. One type had the ordinary mosaic appearance and was not different from 'Zeeland Blue.' One type only, consisting of one plant, was very strong, big, broad and smooth leaves, more resistant to Phytophthora infestans, but some secondary branches of this plant (second growth branches) had the ordinary 'Zeeland Blue' type.

"This last plant was very interesting; it gave tubers of three types. One being the ordinary 'Zeeland Blue.' One being the dark violet type. One being a long pink type.

"The pink tubers produced in 1914 again plants with long pink tubers, but these plants had not the great resistance to Phytophthora and mosaic.

"The white tubers of 1913 produced plants with dark green, smooth and broad leaves and white tubers not mosiac.

"Here you see another example of bud-variation in which not only the colour of the plants and tubers have changed, but also the shape of the tubers and of the haulms, and their susceptibility to mosaic disease."

When we compare the case described by Mr. van Luyk and the case observed in "Arran Victory," the evidence would seem to indicate that new and distinct varieties may develop by bud-variation, and I look forward to the further investigation of the problem with great interest.

Messrs. Sutton & Sons and Mr. H. Bryan, of the Ormskirk trials, very kindly undertook to grow some tubers of the variations from "Arran Victory," including those described here, to test my findings, but up to the time of writing this paper I have not had the benefit of their observations.

I am deeply indebted to Dr. H. M. Quanjer for checking my observations during a visit to me last summer—a visit full of interest and instruction to me—and for his assistance in preparing this paper.

This was followed by "Potato Breeding, Selection and Development Work in the British Isles."

POTATO BREEDING, SELECTION AND DEVELOPMENT WORK IN THE BRITISH ISLES.

By F. J. Chittenden, F.L.S., V.M.H., Director, R.H.S. Experimental Gardens.

The theme given me embraces three parts : (1) Breeding, *i.e.*, the selection of parents and the raising of seedlings of potatos and all it entails ; (2) Selection, which involves the choice of plants and material from which to raise crops for consumption ; (3) Development, which, I suppose, relates to the extension of potato-growing and improvements in methods of cultivation and utilization.

The principles and practice of crossing, seed sowing and seedling raising and the precise methods followed to attain particular ends have been dealt with by others. It will be not without interest and value, however, briefly to review what has been accomplished and see where at present we stand.

Potato breeders have had two aims,

(1) To produce new varieties, improvements in some way upon the old.

(2) To discover the heritable characters in potatos and the way these characters are inherited.

During the past few years the latter aim has been pursued, particularly in England, by methods made possible through the rediscovery of Mendel's laws and the impetus given to such work by the translation of Mendel's paper and its publication in our Journal. Dr. Salaman, Capt. Lesley, Miss Breeze, and Mr. Collins will, I hope, give us some further results of the work which has already shown the relationships between the various forms of tuber, colours of plant parts, and habit of growth. When the more subtle characters of cropping-capacity, growth-period, flavour, and disease-resistance are run to earth we may hope that the production of any particular form of potato desired may be a matter of certainty.

Hitherto, even in the hands of the most successful, the nature of the progeny raised has been largely a matter of chance, but even so a great deal has been accomplished.

Ninety years ago yesterday Dr. John Lindley read before the Horticultural Society of London an account of some experiments with potatos carried out in our Gardens, then at Chiswick, in which twenty-five of the best known varieties of the day were grown in comparison with twenty seedlings raised by the President of the Society, Thomas Andrew Knight. From the list he gave several things are apparent. First, that most of the best varieties were of American or Continental origin, principally the latter. Second, that some of them had as heavy cropping capacity as any of the

present-day varieties. Third, that the average level attained by Knight's seedlings was higher in this respect than that of well-known varieties. Fourth, that few of the varieties then grown are in existence to-day. Fifth, that the common yield of potatos was somewhere in the neighbourhood of five tons to the acre.

I do not know whether many of Knight's seedlings were named, but one, Downton Yam, had a considerable reputation and is still grown in remote parts of the British Isles, to which it was sent from the Society's Gardens. Ashleaf Kidney and Champion were also grown, and both gave high yields. The former is said to have given usually 11 or 12 tons to the acre, but under special (though not extraordinary) cultivation as much as 22 tons. Whether this was exactly like the form known as Myatt's Ashleaf I am not sure, but this and several much like it were possible seedlings of the older Ashleaf. The Ashleaf type seeds freely and produces many seedlings closely resembling itself.

Many of the potatos mentioned were of the long kidney form and more or less coloured. The Yam was so named by Lindley because " in substance and appearance it resembles a White Yam . . . it is large, solid, mealy, white and delicate."

Though modern varieties are not better than the best of that day in yielding power, the general level of excellence is probably higher now than it was then, and substantial advances have been made in other directions if we may judge by illustrations and descriptions of older varieties that have come down to us. We have fewer of the long cylindrical varieties that were then so common. Large tubers of ungainly shape, with deep eyes and projecting eyebrows, are now rarely offered. Present-day taste is for a medium-sized, mealy, white-fleshed potato, and of these we have many ; watery, soapy varieties and those which grow hollow in the middle, are soon eliminated, no matter what their other good qualities. Some may deplore the loss of the small, waxy, yellow varieties, but these, pleasant as many find them to eat, are luxuries, since they do not crop well. They may still be obtained and grown by those who do not look for a heavy crop. The best salad potatos belong to this class. A special trade has also arisen which provides chip-potato merchants with varieties that take up comparatively little fat in the cooking ; while caterers desire a potato that can be cooked twice without blackening.

The blackening of the flesh on cooking is apparently not altogether a varietal character, but is dependent partly upon the nature of the environment in which the potato is grown, and the matter is not well understood. Certain varieties are, however, more prone to it than others, and I think King Edward owes some of its popularity to freedom from that defect,

The British public prefers, on the whole, white or brown-skinned

potatos, though in some countries, *e.g.*, Australia, those with coloured skins are liked best. King Edward is an exception, perhaps because it is easily recognized.

It is, perhaps, as well to review all the characters looked for in good potatos, since so many are now interested in raising them, and no variety is likely to find favour that does not possess all or nearly all the good and none of the positively bad characters.

While bearing in mind the qualities demanded by the public, the grower for his part desires varieties which produce a good number of medium-sized potatos; he does not want a heavy crop of very large ones, nor many small tubers; he wants these tubers "at home" on short stolons; the variety should not be prone to second growth; for second-early and main crops the grower wants a haulm that covers the ground, and prefers one with few not many shoots, large not small foliage; and, speaking generally, of ascending rather than of quite erect habit; the haulm should in any case not be too tall. The wants of the grower of early potatos vary in this matter in different districts. In Lancashire room must be left for intercropping; in other districts a top that covers the ground like that of Ninetyfold is preferred; while in some districts, where sea winds blow strong, Dargill Early is popular because it almost lies upon the ground. For maincrop varieties the tops should not remain green so long that they need to be mown before the potato-digger can deal with them—a serious fault in Irish Chieftain. Varieties reaching maturity quickly and others ripening not so quickly are required. Resistance to or immunity from all the diseases to which potatos are open is greatly to be desired, and for all new varieties now, so far as "blight" and "wart disease" are concerned, it is indispensable. The tubers must not be so tender as to suffer damage in lifting or handling.

Is it to be wondered at that no potato of the present day combines all these qualities? Some varieties approach the ideal very closely, and if I might make a suggestion that may evoke criticism, I should say that Great Scot, raised by Mr. Mair, approaches it most nearly.

Many names stand out among those who have given us these excellent varieties. Mr. Nicholl (who raised Scottish Champion), Messrs. Sharpe (Express, Victor, etc.), Mr. Chapman (who raised so many of Messrs. Dobbie's special varieties), and Mr. Clark (to whom we owe Magnum Bonum and many excellent varieties introduced by Messrs. Sutton), Miss King (Flourball), Mr. Harris (Sir John Llewelyn), Robt. Fenn (a great number of well-known forms), Rev. Aikman Paton (the raiser of Messrs. Sutton's Castle line), Dr. John Wilson (whose work Mr. Robb has described), Mr. Brown (Witch Hill), Mr. Paterson (Victoria), Mr. Mair (Great Scot), among living raisers Messrs. Farish and McKelvie; and among them all, the greatest, Mr. Archibald Findlay, whose loss we have so recently had to deplore.

Some among them gave us many varieties that have taken a great place in potato cultivation. This cannot all be due to chance. Rather is it due to insight. Few of the older of them had any knowledge of methods open to present-day workers, but they had that imagination which is necessary to all good work, without which scientific-breeding is as likely to fail in securing an end, as haphazard seed-sowing. Without this imagination no man can be great; this imagination they had, and they used it, and we may surely reckon them great men.

It is, perhaps, worth while to consider the incentives to the raising of better varieties that actuated such men.

Over a hundred years ago our Society offered premiums for the raising of good new varieties. This offer brought forth nothing of outstanding excellence, and when it was withdrawn, the work still went on. That spirit of divine discontent that informs so many gardeners and the common desire for something new drove many to raise new forms of which there was a constant but slow stream. But in 1845 came an event, the outbreak of the potato disease, which proved so devastating that the life of the people was threatened. The idea that the disease was due to varieties becoming old, that varieties wear out, an idea which had been fathered by Thomas Andrew Knight fifty years earlier, caught people's imagination, and that most powerful incentive to progress—the desire to help their fellow-men—gave a fresh impetus to the work, which carried it on far longer and much further. Scottish Champion and Magnum Bonum emerged and still survive. May Queen and Flourball belong to this era too. Later still, Up-to-Date set a standard which none has surpassed, and it soon outdistanced all its competitors. It maintained its lead after the tercentenary of the introduction of the potato and the "boom" which was associated with it, when the raising of new seedlings received another impetus which had scarcely weakened before the beginning of the latest phase. The aim now is to raise new and good varieties immune from wart disease to take the place of Epicure and Ninetyfold, Sharpe's Express and May Queen, Up-to-Date and Magnum Bonum, Sir John Llewelyn and King Edward. Many steps have been taken toward this end since Mr. Gough's satisfactory examination of the farmer's claim that Snowdrop and Schoolmaster never suffered from wart.

This brief account would fall short if it did not mention the enterprise and efforts of Mr. A. W. Sutton and of those associated with him in collecting and examining and breeding from all procurable wild types of tuber-bearing Solanums, for though these experiments have given no hope that in that direction lies the goal of the seeker for blight-resistant varieties, yet the efforts have not been in vain. As a matter of fact only the form known as S. etuberosum of Lindsay

(S. edinense) has proved at all useful as a parent of good cooking and cropping varieties when crossed with our domestic varieties and that has failed to confer immunity from blight. The Rev. Aikman Paton used it, and others have done so too. The parents of Mr. Archibald Findlay's varieties are not easy to ascertain, but he apparently used some from South American sources.

Mention must be made of the enterprise shown by many firms in seeking for and testing vast numbers of seedlings or supposed seedlings from world-wide sources. To them is due much of the progress that has been made, and their work calls for no small meed of praise.

Associated with these different waves of seed-raising went also waves of name-coining and the multiplication of synonyms. This is not the place to discuss the source of synonyms, I have done that elsewhere. But it is as well to mention the fact that our Society has always been active in pointing out where two names had been given to the same thing. For instance, in 1874 in the garden at Chiswick potatos were represented by 271 names, which were reduced by eliminating synonyms to 115! Kentish Ashleaf Kidney had 18 synonyms! Doubtless many of these varieties with two names or more had their origin in more than one seedling, but certainly not all. One has only to study the relative number of synonyms to ascertain what varieties most took public fancy, and the same is true to-day. Up-to-Date easily leads the van, but it has many competitors, as our own trials and those at Ormskirk have shown. It is to be hoped that the day is not far distant when one variety will have one name and one only.

Selection in the case of the potato implies variation within the progeny of a seedling. Variations may be such as are constant and handed on from one year to the next, or they may be fluctuating and incapable of being carried over without change.

The only variations of the former type which have come to my notice, and for which the evidence seems indubitable, are variations in colour of tuber skin (*e.g.*, from pink to white, from mottled to self-pink) or in flower colour (from coloured to white), and in russet to smooth skin. Mr. McKelvie's variations seem to be an instance of the first of these variations. Another type of variation that seems to be constant is that seen in certain varieties such as Great Scot, where some plants grow taller than the majority and remain true to this character, as Messrs. Dobbie have shown.

On the other hand, all attempts at maintaining round or kidney stocks of Up-to-Date, for example (where this variation in form is frequent), by selecting seed tubers from the general stock of these forms, have in all cases, I believe, as in mine, proved abortive. So also have both hill selection of heavy-cropping plants (without reference to their appearance when growing) and mass selection of larger tubers.

Neither method has appreciably raised the general yield within a variety. Continued selection of small tubers has, in the south, given a higher percentage of small yields and small tubers, due, I feel sure, to the preponderance of small tubers at the roots of plants attacked by the diseases of which the symptoms are leaf-roll and crinkle. It is in all probability the increase of these troubles which has led to the idea of the degeneration and subsequent death of a variety from old age. It is improbable that old age, as we understand it in human beings, occurs in a variety of plant propagated vegetatively; and degeneration is nothing but an accumulation of disabilities in a certain section of a variety which has grown under conditions conducive to their acquirement. When the variety is grown under other and favourable conditions, degeneration does not occur.

We, at Wisley, have been for some time endeavouring to sort out the factors (using the term not in the Mendelian sense) which determine yield in potatos, and have published some of the results. These experiments have shown how extraordinarily difficult it is to get an accurate answer to a question put to potatos experimentally, and this matter of leaf-roll and similar "degeneration diseases" is in part answerable for the difficulty. Quite apart from it, however, the individual yield-capacity of seed tubers, all controllable things being equal, varies enormously, and the best method apparently of comparing crops (from two different varieties, or from two different treatments) is to have many plots. Forty single-plant plots will give, we find, results within 2 per cent. of the truth. The number of plots has to be increased greatly to get nearer than this, while half the number would give a margin of experimental error as large as 7 or 8 per cent. Simply to plant two rows or two large plots of potatos side by side without taking great precautions and to attempt to base conclusions upon the results is likely to be most misleading.

We have also attempted to estimate the chemical composition of different varieties of potato, but so far have not been able to reach definite conclusions. The problem has proved more difficult even than we anticipated owing to individual variations in composition, and much more work remains to be done before any conclusion can be drawn. Whether selection for seed purposes of tubers rich in starch or protein will improve the starch-yield or protein-yield in a variety is one of the questions still awaiting solution.

The utilization of the results of these experiments belongs to the region of development, and I can only briefly outline them. Reference can be made to our Journal for many details. Apart from kind of soil, manures, climate, water supply and cultivation, most important factors in determining yield are source of seed (often making a difference of double weight), treatment of seed tubers, sprouting (tubers sprouted in the light increased the crop by about 2 tons to the acre),

number of sprouts left at planting time, cutting seed tubers and the treatment of cut tubers, size of seed tubers, time of planting, distance apart of plants and so on, all influence the yield. Mr. Cuthbertson and others have shown that "second-growth" tubers give a higher yield than more mature ones. I have made no experiments upon this, but all other methods of obtaining immature seed, such as lifting while green and so on, have with me failed to produce the results that are given by growing seed from a moister climate. I think we have much yet to learn concerning the idea that immature seed, *per se*, is best, but at present it is a useful idea to act upon. The fact that, of seed tubers grown at Wisley, those from peat-bottom land give better yields than those grown on the sandy loam a few yards away may be suggestive.

The CHAIRMAN said that, in view of the Ministry's change of policy in allowing susceptible varieties to be planted in infected areas, the importance of the work of raisers of new varieties was greater than ever. Immune varieties were now wanted equal in every way to King Edward and Up-to-Date. He then invited discussion.

MR. R. FIFE: In 1917 I saw growing among Great Scot a plant with erect haulm, a month later in maturing and free flowering. In 1918 it produced a 27.2 per cent. larger crop than Great Scot. Its produce was planted in light soil in 1919, maintained its distinct characters and gave 37.2 per cent. greater yield. On heavy soil in 1920 it gave 30 per cent. greater yield It was sent to Ormskirk for trial, but was there pronounced to be indistinguishable from Great Scot. It was subsequently examined by a member of the Synonym Committee at Edinburgh, who thought it distinct on account of its free production of pollen.

MR. MARTIN SUTTON: If mutation is possible in potatos, the facts are of the utmost importance to science as well as to the practical grower. Mr. McKelvie gave me the opportunity of growing his No. 3 mutation, and we found that the characters he has described were evident in our cultures. No. 3 was quite distinct from Arran Victory. We have often been deceived by what we call "ground-keepers." I should like to ask Mr. McKelvie whether he is certain that the nine white tubers came from the sport of Arran Victory which he had planted, and not from a ground-keeper.

MR. MCKELVIE: Mr. Sutton has asked a pertinent question. I can only say that I took every precaution to prevent mistakes and that the sport which gave the white tubers was planted on ground which for the previous eight years had been under grass.

DR. SALAMAN thought there was no reason to doubt that Mr. McKelvie had actually to deal with a definite and probably temporary variation. Such variations are extremely rare, and he had seen only

one single case of genuine mutation among all the varieties he had had under close observation. The purple colour of Arran Victory was due to three factors and probably a colour inhibitor has been developed in the case of the variation now being considered.

Mr. Sutton said that not only was the tuber colour distinct, but the foliage was quite distinct from that of Arran Victory. (See Mr. McKelvie's paper).

Miss Breeze said she thought that Mr. Fife's variation from Great Scot should certainly be regarded as a distinct one if much pollen was produced. She added a tribute of praise to the work done by the older potato breeders—especially to that of Mr. Findlay.

Dr. Quanjer referred to the regrettable changes often made in the names of potatos, Paul Kruger of the Continent being known as President, Scottish Farmer and Iron Duke. He suggested that a resolution should be put to the Conference that it is not an honest policy so to change names.

The Chairman pointed out that both in England and Scotland, Synonym Committees were at work, with the object of preventing this undesirable practice, and suggested that France, Holland, and other countries, might well follow suit.

Dr. Burns said that most of the seed tubers planted in the Bombay Presidency were obtained from Italy. India had its own special problems. It was neither "blight" nor "wart," but degeneration was severe on account of the attacks of soil fungi which did great damage—both in field and store. Storage rots were extremely serious in India, probably on account of the very high temperatures (85 deg. to 95 deg. F). Varieties which could be stored at this temperature were greatly to be desired. Trouble was also caused by the potato moth, which was overcome by petrol fumigation; by mites causing leaf-roll and "burning" which was dealt with by singpray with lime-sulphur; thrips and a Jassid were among the animal pests India had to contend with. There is an increasing demand for potatos in India, which is difficult to meet. Breeding-work had hitherto made little progress, for the varieties most commonly grown produced little pollen. A start had, however, been made with Sutton's Flourball.

Mr. Kulkarni referred to a serious bacterial disease of potatos in India, known as the "ring disease." The only methods found to avail in dealing with it were seed selection, which was difficult to carry out on a large scale, and proper choice of planting time.

Capt. Lesley said that Dr. Salaman and he had, so far, only found one case of a mutation which had proved constant. He distinctly remembered Mr. Fife's plant and its copious pollen, growing at Edinburgh and, when he saw it there, thought it distinct. So far the evidence of mutation advanced by Mr. McKelvie and others referred

to the tubers, but it seemed quite possible that mutations might occur in other parts as well, resulting in a mosaic of different kinds of tissue.

Mr. Gram of Denmark said that little progress in potato raising had been made in his country, but a breeding station had recently been instituted since the potato was becoming a more and more important crop, especially for alcohol production, and men were being trained in England to carry out the work.

Mons. H. L. de Vilmorin said that fortunately wart disease was at present unknown in France. Possibly the explanation lay in the climatic conditions, since both India and Italy were also free. They had, however, similar degeneration problems which they found could be met by change of seed from the north-west to other parts of the country. The French clung to old varieties which were sometimes found to become weak, but good strains were generally to be discovered in remote provinces from which stocks could be renewed.

Mr. Buchanan said that in Tasmania the method of selection of plants for seed production had given excellent results in preventing degeneration. All plants dying down early or remaining green beyond the normal time were rejected.

Mr. Murphy said that his experience in Canada was that selection of plants for seed in the way described by Mr. Stuart would not lead to success. He was surprised to hear that the yields of 90 years ago were sometimes as high as those obtained to-day, for the evidence given before the Select Committee on Potato Growing gave no indication of this. He thought the greatest advance in potato production during the last century had been the introduction of Champion, which had marked the turn in the fight between grower and blight. Champion was responsible for the grower's victory.

Prof. Potter considered degeneration of potato stocks to be the result of climatic and soil variations and that disease resistance depends to a great extent upon manuring.

Mr. F. Hiam said he thought Up-to-Date the best potato for growers and consumers ever produced. At first it was too vigorous and needed no manure, but gave 15 tons to the acre. Up-to-Date would grow anywhere (unlike most varieties) but succumbed to blight. Blight he thought, had followed manuring with artificial manures.

Prof. Foex said that France was free from wart disease at present, as were Italy and Spain. Perhaps the climate was too hot, but against this was the evidence that wart disease can grow in hot climates. He thought there had been plenty of opportunity for its introduction since the Germans had planted largely behind their lines during the war.

The Chairman, in closing the discussion, said that hill selection in the south had given place to the importation of more vigorous stocks from the north—a method which M. Vilmorin had shown to be the practice in France.

SECOND SESSION.

WEDNESDAY, November 16th—3 to 5.30 p.m.

Sir Arthur Griffith-Boscawen in the Chair.

THE EARLY POTATO INDUSTRY.

By J. M. Hannah.

Some fifty years ago it frequently happened that the previous season's crop of potatos was finished weeks before the new crop was ready for lifting. Since the introduction of late keeping varieties, however, regular supplies have been obtainable in an average season throughout the whole year. In some cases the old crop has been so abundant that large quantities of excellent quality have been fed to cattle. This fact has tended to lessen the demand for new potatos for a limited period; but, in general, after these are available the chance of finding a market for old ones is comparatively small. In common with other fresh vegetables, new potatos have a flavour which ensures them a ready sale, and there is little reason to doubt that this will continue to be the case so long as they can be offered to the public in an attractive form.

Early Districts.

Certain districts have made a speciality of catering for this demand. Notable amongst these are the island of Jersey, Cornwall, a part of Lancashire and Cheshire, and Ayrshire in Scotland. Other districts have in recent years contributed to the supply, but only to a limited extent, and mainly for local consumption. The production of potatos for the early market has been carried on in the island of Jersey for many years and has grown to such an extent that it is difficult for an outsider to realise the magnitude of the industry. Situated, as it is, far enough south to secure the advantages of brilliant sunshine and comparative freedom from spring frost and yet near enough to be within a reasonable distance of the best English markets, the island can well hope to retain the monopoly it has so long enjoyed of supplying the demand in the earlier part of the season. The mean temperature is 60 deg. Fahr., and the rainfall about 30 inches per annum. Land is under crop which in many countries would be lying waste, and some of it is so steep that one wonders how the soil keeps in position. Earthen banks and hedges of shrubs and trees provide good shelter

from wind storms. About 7,000 acres, or one third of the entire island, is set apart for the growth of potatos, and 50,000 tons are annually shipped to market. The rotation usually followed is to grow three crops in succession, followed by grain, hay and pasture for two or three seasons. Seaweed is collected around the coast and applied to the land along with the dung made on the island. These are skimmed in during the winter months and the land is again ploughed in the spring to a depth of 9 or 10 inches. After ploughing the labour is mostly done by hand and many of those employed to cultivate and harvest the crop are imported from France. The main portion of the crop is planted in February. The sets are planted very closely, the rows being 16 inches apart and the sets 10 to 12 inches apart in the row. Artificial manure, containing 5½ per cent. ammonia, 18 to 20 per cent. phosphates, and 5 per cent. pure potash, is sown broadcast and harrowed in before planting. The crop is usually ready for marketing about the end of May, and the average yield is from 7 to 10 tons per acre, but many of these potatos are lifted before reaching maturity. Growers lift the crop and cart the produce to the shipping port of St. Heliers, where it is sold to merchants, packed in small barrels and sent to the different markets.

Cornwall.

The practice in Cornwall does not vary greatly from the methods adopted in Jersey. The rainfall there is around 40 inches, and the mean temperature about 51 deg. Potatos are grown in consecutive years on the same land, and the work is chiefly done by hand labour. The land is ploughed in spring to a depth of 6 or 7 inches after an application of seaweed and farmyard manure at the rate of 40 to 50 tons per acre. Some growers apply the dung on the surface after the land has been ploughed. About 16 cwts. of guano and dissolved bones are sown at the time of planting, and 4 cwts. nitrate of soda as a top-dressing when the crop is growing. May Queen and Sharpe's Express are the varieties grown, and 40 cwts. are required to plant an acre. The yield runs from 5 to 8 tons per acre at the beginning of the season, and lifting usually begins about the end of May.

In Cheshire and Lancashire a considerable area of land is devoted to the growth of potatos, and a portion of the crop is lifted in a green state and sent direct to market. The rainfall is about 32 inches per annum. The mean temperature is 48 deg. The district has not the same immunity from frost as further south, or near to the coast line. Potatos are grown in rotation with other crops and are generally planted after grass in the previous year. The land is ploughed to a depth of 9 or 10 inches in late winter and farmyard manure is applied in the drills at the rate of 15 to 20 tons per acre at the time of planting. Artificial manure is sown at the same time at the rate of 6 cwts. per

acre. This is compounded so as to give on analysis 8 per cent. ammonia, 20 per cent. phosphates and 5½ per cent. potash. The varieties grown are Epicure and Ninetyfold. The seed is usually cut, and 14 to 16 cwts. are required to plant an acre. The drills are drawn 28 inches wide and the sets are laid 12 inches apart in the drill. One man and one horse will scarify, drill, harrow and plough up one acre in one day. Raising of the crop begins in the third or fourth week of June, and the average yield at the beginning of the season is about 5 tons per acre. Crops are generally cleared before disease does any damage. Savoy cabbages are frequently grown as a catch crop after the potatos are lifted.

Ayrshire.

I now come to that part of the subject with which I am more immediately connected, namely, the industry as carried on in the county of Ayr. One may well ask why a district situated so far north, and with few natural advantages, should have attained such prominence in the production of a crop which is so liable to suffer damage from frost and storm. It has been suggested that a current from the Gulf Stream strikes the coast at this particular point and moderates the temperature. This theory, however, is not supported by the reports of the Meteorological Society. According to them the temperature does not vary much as between the east and west of Scotland. The mean temperature of both is 48 deg. The only marked difference is in the rainfall, which runs from 23 to 25 inches in the east, and 38 to 40 inches in the west. Doctors are reported to have sent their patients in past years to Girvan, which is the centre of the industry, in the belief that a district which produced early potatos must be well suited, as regards climatic conditions, to the needs of certain ailments. Farmers, on the other hand, claim that but for them the place would never have been heard of as a health resort.

The district stretches from Ballantrae in the south to West Kilbride in the north, a distance of about 50 miles along the seaboard. The width varies from about 100 yards to, in some places, half a mile or more from the seashore.

Soil—Manure.—The soil ranges from drifting sand to medium loam, and much of it is of poor quality. The estimated acreage of this crop annually in the county is about 8,000 acres. Potatos have been grown on the same land from 30 to 50 consecutive years. Large quantities of seaweed are washed ashore during the autumn and winter months and spread on the land at the rate of 30 to 40 loads per acre. Dung is brought by rail from Glasgow and applied at the rate of 12 to 15 tons per acre. An effort is made to alternate the application where both are available, but it is seldom that both seaweed and dung are applied to the same land in the same year.

Attempts have been made to produce crops without either dung or seaweed, but these have not been attended with a great measure of success, especially in a season when the rainfall happens to be under average. Where either dung or seaweed has been applied the crop does not suffer to the same extent during a time of drought, and no application of artificial manure will make up for this want. It is probable that one of the chief reasons why Ayrshire has attained to its present position as a potato-growing county is because of the large quantities of farmyard manure applied to the land on which the crop is grown. During the past summer a farmer in the district found a motor drawn up alongside of his manure heap. The motorist said that he had come from 30 miles beyond London, and as he had never seen so much manure together before, he had pulled up to estimate the dimensions of the heap. In addition to farmyard manure and seaweed, artificial manure is applied at the time of planting the seed at the rate of 11 to 12 cwts. per acre. This manure is frequently compounded on the farms and consists of sulphate of ammonia, superphosphate potash and bone flour, in such proportions as to give on analysis 9 to 10 per cent. ammonia, 18 to 20 per cent. phosphates, and 3 per cent. of potash.

Cultivation.—Preparation for the crop begins about October, when dung and seaweed are spread on the land and ploughed in during the winter to a depth of 9 or 10 inches. This work is usually completed about the end of January, and planting begins as soon after the middle of February as weather conditions permit. At this season of the year great patience is often required on account of the fickle nature of our northern climate. Quite frequently the land is not in condition for working on for weeks together, and nothing tends so much to cause failure as to work on the land when it is wet. It may not be considered economical to keep horses standing in the stable, but it is oftentimes more profitable to have both men and horses idle rather than working on the land when it is not in order. A single tine of the harrows is generally sufficient to make the land fit for drilling. The less treading on the land after it has been properly ploughed the better will be the chance of a good crop. Treading only tends to solidify the soil, and the potato loves freedom for root expansion. The drills are made by a double drill combined plough and manure sower, and are drawn across the plough furrows. The manure is sown at the same time in the bottom of the drills. Three pairs of horses harrowing, drilling and covering the seed, one horse carting out seed and manure, together with 9 women laying the sets out of boxes will plant from 5 to 6 acres per day.

Treatment of Seed.—When the crop is being raised, medium-sized seed are selected by hand, stored in boxes, and put away for the following year's crop. The practice of sprouting the seed is now

universal. The first attempt at sprouting seed potatos was made in the district about 40 years ago. The tubers were laid out on the floor 15 to 18 inches deep some weeks before the usual time of planting and covered over with a heavy layer of cocoanut fibre. In course of time small shoots developed and the seed was taken out to the field and planted in the usual way. The boxes used in the district contain from 42 to 48 lbs. or three-and-a-half times the quantity of the Jersey boxes. Most of the buildings used for storing the seed in boxes have been converted from other uses and are not as suitable as a few which have been specially built for the purpose. The most essential requirement is light, and in order that the best results may be obtained it is necessary not only to have a well-lighted house but also to have a space between each tier of boxes. Where this is not done it will be imperative that the boxes be shifted during the winter and spring months to ensure the seed being uniformly sprouted. An early crop depends more almost than anything else on the proper handling of the seed both before and at the time of planting. Success to a large extent depends on the uniformity of the plants, and where any irregularity occurs the later plants are either sacrificed or the harvesting of the whole crop is delayed till the more backward plants mature.

Varieties.—Epicure is now almost the only variety grown. It has increased in favour on account of its vigorous habits and the rapidity with which it recovers from the effects of frost and storm. The most popular size of seed weighs from 2½ to 3 oz., and 28 to 32 cwts. are required to plant an acre. The drills are drawn 25 inches wide and the sets are laid 12 inches apart in the drill. Epicures are only grown to a limited extent outside of the county and opportunities for a real change of seed are practically confined to its boundaries.

Towards the end of April the young shoots appear above the ground and a light harrow is passed over the drills in order to kill as many annual weeds as possible. After this the land is cultivated between the drills and hoed by hand labour. At a later stage the land is drill cultivated as deeply as possible, and immediately before the haulms meet in the drills a moulding up plough is used to finish up the work. In an average season the crop is ready for lifting about the middle of June, and it is marketed in increasing quantities till the end of July. The sandy soil matures earlier and as a rule does not produce as heavy a crop, and on this account is lifted first, leaving the better soil and crop till more matured. The yield about the beginning of the season will average 5 tons, and later on will run from 12 to 16 tons per acre.

Crop.—The crop is sold growing either by auction or privately to potato merchants. Very few farmers market their own crop. The practice has almost become general for growers to invite merchants to

attend at the farms on a certain day as the crop is nearing maturity, when it is sold by auction in lots of 5 to 20 acres. Merchants take the risk of the crop and also of the market price. The risk is considerable, but the profits are proportionate, and a small certain profit is not nearly so attractive to the average purchaser as the possibility of a handsome profit, even if the alternative should be a probable loss. Merchants buy on the same farms year after year and can estimate fairly accurately how many tons a growing crop will yield per acre. They also provide labour for lifting the crop, and for this purpose large numbers of workers, both male and female, are brought over from Ireland annually. These workers receive accommodation at the farms where they are for the time employed, and are allowed as many potatos as they can use and coals for cooking. They work in gangs of 20 to 30. One worker throws out the tubers with a hand fork, while another gathers and sorts them according to size, etc.; six or seven pairs of workers are expected to dig, gather and sort an acre a day. The grower carts the produce in barrels to the nearest railway station, from which it is dispatched in barrels, bags, or bulk to the different markets. The principal markets are the large cities and industrial centres throughout Scotland and the north of England, and on occasions supplies have been sent to Manchester, and even as far south as London.

Few growers ever attempt to spray their crops. They prefer to get them away before there is any chance of disease; but in a wet season losses do take place from this cause. Probably the most serious loss occurs if the crop is lifted when in a semi-green state, and seed taken from such a crop at this stage is very liable to go bad in the boxes; 25 per cent. to 50 per cent. loss is not uncommon under such circumstances.

On some of the land which has been under potatos for a long term of years indications are to be found of a falling away of the produce, and it may be necessary to change the crop in order that the best results may be obtained. Land in the district which has produced 16 tons per acre in the middle of July has recently produced less than half that quantity. Experts have expressed the opinion that the cause of failure was stem rot in the plants, but seed taken from the worst affected plants and planted elsewhere has given quite satisfactory results. This would indicate that the trouble, whatever it is, is in the land, and yet analysis of the soil has not shown anything to account for the failure.

Catch Crops.—The catch crops grown are Italian ryegrass, rape and barley. Italian grass occupies the greater acreage and promotes a favourable condition in the soil for the succeeding crop. Annual weeds such as groundsel, chickweed and nettles spring up with the grass and retard its growth to such an extent that the feeding obtainable is reduced by 50 to 100 per cent., compared

with what it was in earlier years. The difficulty of preventing these weeds from seeding is almost insuperable, and thereby the trouble increases from year to year. Rape can only be successfully grown at intervals of four or five years on account of its tendency to finger and toe disease. When this is absent, it provides a valuable feed for sheep at a comparatively small outlay. Barley is grown and cut green for forage purposes and affords a succulent food for dairy cows in the district during the autumn months. It is a curious fact that oats have only on rare occasions been successfully grown for this purpose. When oats and barley have been mixed and sown together the former has been eaten up in the early stages of growth by eel-worms, while the barley was left to grow to a full crop.

Cost.—In 1914 the cost of producing a crop of early potatos was estimated at £24 to £28 per acre. Prices have recently fluctuated to such an extent that it is difficult to give corresponding figures applicable to the present time. Labour, certain kinds of manure and seed have cost three times what they did, and it would not be safe to reckon the cost at less than two to two-and-a-half times that of pre-war days. In the year 1896 the crop on three farms was sold by auction at prices from £11 2s. 6d. to £22 10s., while on other three farms in the same season the prices realised were from £13 15s. to £32 5s. 322 acres were sold in 57 lots and the average price was £19 per acre. The varieties included in the sale were Goodrich, Dalmahoy, Dons, Puritans. Harbinger, Sutton's Seedling and Regent and Fiftyfold. The newspaper report of the sales stated that the crop looked remarkably healthy and was sure to raise well. In 1906, or ten years later, the varieties sold by auction included Ruby Queen, Epicure, Ninetyfold, Nonsuch, May Queen and Puritan, and prices ranged from £17 to £36 10s. The average was slightly over £24 per acre. In 1910 about 400 acres realised £27 per acre, while in 1915 prices mounted up to £33 per acre. It is a noteworthy fact that in August of that year, or one year after the beginning of the great war, potatos were loaded on rail at 30s. to 35s. per ton, and that this was the current price at the time for good ware. In 1917 about 750 acres were sold by public auction at an average price of £93 10s. per acre. Prices reached the climax in 1920, when 14 acres were sold by public auction at the record price of £181 per acre, or four times the value of the land on which the crop was grown. Other lots were sold at correspondingly high figures. Merchants lost heavily, and more than one firm, unable to stand the strain, was forced into liquidation. The inevitable reaction took place during the past season. Prices were in most cases less than half of the previous year, and some had to accept prices which did not cover the cost of production. On account of the long period of drought the crop was the smallest for many years,

but, notwithstanding this fact, the supply was equal to the demand. The miners' strike and the unsettled condition of the country was no doubt largely responsible for the lessened rate of consumption.

Prospects.—One is frequently asked as to the prospects for the future. Anyone who is rash enough to give a decided opinion on this subject has only to be reminded of past experience in order to shake confidence in prophecy. It is not safe to predict as to either crop or prices very far ahead. A night's frost or a short spell of drought is liable to upset all calculations. An important point, however, in connection with the future, is the fact that prices of produce are falling more rapidly than the cost of production, and until these factors adjust themselves the outlook is shrouded in uncertainty.

Sir Thomas Middleton said he had long been impressed by the Ayrshire enterprise of early potato growing and by the fact that Mr. Hannah, in the west, was already selling early potatos while he, in the east, was still endeavouring to dispose of his old ware. He felt sure, however, from his experience in growing potatos in the east of Scotland that there were climatic differences which the plants appreciated, but which were not revealed by meteorological records.

Mr. James Wright, of Co. Down, remarked that Mr. Hannah's paper was that of a practical man, but some points in it would surprise the ordinary grower. The great quantities of nitrogenous manure used in Ayrshire were astonishing, especially in view of the fact that larger crops were grown in the west of Ireland than those to which he referred. In the north of Ireland it was found that main crop varieties would not keep if such heavy applications of artificial manures were made. He thought that the continued use of superphosphates had probably caused a serious amount of soil acidity and that this might be answerable for the reduction in crop to which the speaker had alluded. He thought that ground mineral phosphate and nitrate of soda might be used with advantage. The heaviest main-crop yields were obtained where two nitrogenous manures were used together. In the U.S.A. sulphate of ammonia, together with nitrate of soda were found, as the result of ten years' experiments, to be the best manures. He also suggested the desirability of seeking for an immune Up-to-Date.

Mr. Hall (Derby) advised the use of green manuring and especially of rye for this purpose on heavy soil. He said this gave better results than the use of artificial manures.

Dr. Quanjer said that in Holland, acid mineral manures had encouraged one group of diseases, while the use of lime encouraged another group. The quantities of manure mentioned by Mr. Hannah were greater than those used anywhere in Holland. He cordially

invited growers to go over to Holland and see the results of the Government experiments there.

Mr. Lobjoit referred to what seemed extraordinarily large dressings of manure used in early potato growing in the Penzance district, where seaweed, sand, manure and offals are stacked in layers in large "pies." It is questionable whether such heavy manuring is necessary, although the price obtained for early potatos may often be so high as to leave a wide margin for profit.

Mr. Patullo said he agreed with Mr. Wright as to the probability of soil acidity being answerable for a drop in yield. He had found in the east of Scotland a remarkable response to potash manuring and thought it probable that potash had been used in insufficient quantities during the war.

Mr. Buchanan referred to the "law of diminishing returns" and asked whether Mr. Hannah had found at what point manuring ceased to pay. In Tasmania nitrogenous manures were not required, but phosphatic manures (17 per cent.) up to 8 cwt. to the acre were found profitable. Any amount in excess of this dressing did not pay.

Sir Matthew Wallace said freedom from frost, proximity to markets, suitability of soil and large quantities of manure were all requisite for success in early potato growing. His experience extended over forty years, but for the first twenty without any satisfactory financial result. He deprecated the movement of some seed growers to reduce the standard of purity set up by the Government, and hoped it would be maintained. Incidentally he had found that the best means of securing productive seed was to lift crops before disease appeared and, if necessary, to cut off tops as soon as the crop was ready to lift to prevent maturity. "Immature seed was the perfect article." Possibly degeneration was due to permitting seed to become mature. In the best "seed" potato district in Scotland, the plants could be seen in full growth and even in flower when frost and storm cut down the haulm. Another factor in success in potato growing is the sprouting of the seed which should be done even with late potatos.

Mr. Hannah replied briefly to the points raised. He still held his opinion that not temperature, but larger rainfall enabled early potato growing to be practised more in the west than in the east. He thought it doubtful whether reduction of crop was connected with any particular manurial treatment and said he had carried out no experiments to ascertain the least amount of manure that could be given with profit. There was always a chance of profit with early potatos, although the risks are great. Earliness was the main factor and, if growers could catch the early market, the cost of manuring and cultivation was a secondary matter.

At this point Sir Arthur Griffith-Boscawen was obliged to leave and Lord Bledisloe then took the Chair.

He said he had recently had the temerity to propound a new policy for agriculture, which had become known as the "Potato and Pig" policy. Two things at least were necessary if increased cultivation of potatos was to be a profitable enterprise, *viz.*, to place the potato before the public in more palatable form, *e.g.*, to take the place of the wheat grain, and to find some means of using surplus potatos in a season of glut. Potato starch was now being imported from countries where labour was cheap, but the designers and makers of machinery were increasing the chance of handling the crop economically.

THE INDUSTRIAL AND COMMERCIAL USES OF THE POTATO.

By H. V. Taylor, A.R.C.S., B.Sc., M.B.E.

A review of the programme will show that the papers generally deal with development, production, degeneration or diseases of the potato, and to this paper has been left the privilege of describing the industrial uses to which the crop can be put. The scope or extent of the uses of the potato is naturally largely determined by the chemical analysis, though in practice financial considerations may impose considerable limitations.

Generally the average composition of the potato as grown in Britain, and as determined from the figures published in the Report of the Royal Society (Food War Committee), is as follows:—Water 77.92%, Dry Matter 22.08%—of the latter 1.47% is Nitrogen. Whilst these figures in their present form convey considerable information of importance to the experts on nutrition, their value is enhanced when considered conjointly with particulars showing the form in which these chemical substances appear in the potato and, if possible, the way by which the substances are held together in building up the complete tuber.

On all these matters the information at our disposal is limited, but so far as can be judged from the writings in existence, the potato consists of globules of pure starch floating in a watery protoplasmic medium of a gelatinous character. The latter forms a matrix in which the starch globules are floated and by which the starch and the large volume of water are held together to form a potato tuber. For this reason a British botanist once described a potato as a mass of water held together in a convenient form by a small wrapping of starch. The size of these starch globules plays an important part so far as the value of the potato for industrial purposes is concerned.

The crop in the United Kingdom has in the past been cultivated almost entirely for human consumption and, except for the new potatos in the spring months of the year, the country has generally

been self-supporting. In years of unfavourable seasons and poor crops the supplies have proved deficient and imports have been drawn in. The shortage has been but seasonal, for in years of low harvests prices have risen to such a level as to make the crop a very remunerative one so far as the producers are concerned. Farmers generally develop profitable branches of their industry and in following years their acreage under potatos has been extended, the supply increased and the balance restored. In years of good harvests, or in years of large acreages, the supply may be in excess of the demand, and failing an export trade these supplies, being of a perishable nature, must be used finally as fodder, the price of which always has been low. The consequence is that farmers in years of good harvests compete in markets to clear their crops, with a result that prices fall and the returns to the farmer are at times insufficient to pay the costs of production. On national grounds this country, in respect of the potato crop, can and should be kept self-supporting, and farmers, in spite of the cost of cultivation and the risk involved, are willing and even anxious to grow the crops, provided they can be assured that the production is a financially sound undertaking.

They are as satisfied as farmers ever are with the financial results when the supply of potatos is less than, or balances, the public demand; but they are disappointed when the supply is excessive, and their anxieties would be relieved if some machinery existed in this country for utilising the surplus crop, so that remunerative prices would be secured for the surplus in excess of human consumption. This problem is by no means insular, or confined to any one country, but exists in most places where potatos are grown.

It has been solved, or bridged, in some countries, by the establishment of industries engaged in the manufacture of products from the potato. There the surplus perishable potatos are converted into non-perishable products of commercial use, such as dried potatos, potato starch, dextrine, gums and alcohol.

The possibility of preparing these substances from the potato is admitted; the problem to be considered is the establishment of a similar industry in England, and if established, would the undertaking be a financial success for the manufacturers and the potato growers?

The answer, if based on sound and business reasoning, can only be given after a careful consideration of all the factors involved, viz., capital needed, cost of raw material—with an adequate and continuous supply—cost of manufacture, price at which the finished article can be sold, the extent and demand for it, and the competition on the markets for a similar product made from other sources. To supply most of this information, it has been necessary to study the industries which exist in other countries, viz., Germany, France, Holland and America.

I.—Dried Potatos.

The simplest product that can be manufactured is prepared merely by driving off a percentage of the water, leaving a powdery flaked mass. This is known as "dried potatos."

The potato tubers contain on an average as much as 78 per cent. moisture, and the process of potato drying merely means the evaporation of the greater part of the moisture, leaving the potatos in a form in which they can be kept indefinitely without deterioration. If the dried potatos are to be used for human consumption, it is necessary that the product should be of a good colour, in which case the enzymes, always present in potato tubers, must be destroyed, or discolouration may result. In the preparation of dried potatos for stock food, however, discolouration is of little importance.

The extent to which potatos are dried in countries where this industry is pursued extensively, depends on the size of the crop and the demand for it for other purposes. In years of over-production some portion of the surplus is dried, and farmers are saved from ruinously low prices, while even in the years of short crops, the chats and slightly diseased tubers which are not suitable for human food can be dried and utilised as animal fodder. Germany, France and America dry potatos to some extent.

The way in which the industry sprang into existence in Germany is interesting. In February, 1894, at a special sitting of the Committee of the Society of Alcohol Manufacturers, it was proposed, in the interest of the alcohol trade, that in order to lessen the annual output of alcohol—the supply of which was increasing faster than the demand—a new market should be created, which might utilise some more of the potatos not needed for human consumption, or for the manufacture of alcohol or starch. The Germans, who for some years previously had been drying the pulp after extracting the sugar from sugar beet and using it for feeding stock, commenced similar operations with the potato. This led to the foundation of the Potato Desiccation Industry. In Germany the industry is carried on almost exclusively by farmers on their own farms, singly, or in co-operation with other farmers. The number of these potato-drying installations has increased rapidly in recent years. Their success is largely due to propaganda conducted by the Association of German Potato Dryers, and to the encouragement given by the Government. The rate at which the industry grew is well shown by the following figures:—

Year.	No. of German Factories.
1903	3
1907	118
1911	404
1914	488
1916	841

Normally the German farmers in their small factories do not aim at producing a very high grade article, or of sufficiently good quality to be used as human food, but the industry is largely devoted to converting into fodder for stock a very perishable article that might be otherwise wasted.

Technical Process.—Very little of the technical processes need be described in a paper of this size. Two kinds of material generally are produced.

1. Raw potato slices dried by direct contact with hot air:—Potato Slices.
2. Potatos previously cooked by steaming, dried by passing between rollers internally heated:—Potato Flakes.

Comparison of the two Methods.—Of the 404 Potato Drying Factories working in Germany in 1911, 314 were flake installations. This large proportion may partly be accounted for by the fact that the initial expenses of setting up the machinery does not cost so much as for potato slices. On the other hand the actual working costs (labour, etc.), when slices are manufactured, are less than for flakes.

The Uses of Dried Potatos.—In Germany, where the Potato Drying Industry has by its extent assumed considerable importance, dried potatos are a constant product on the market, prices for both "flakes" and "slices" being regularly quoted in the Return of Market Prices. Though they are fed to stock of all kinds, they are principally used for pigs. Extensive feeding experiments on pigs and horses, carried out at the expense of the state by Professor Kellner (a great authority on the question of animal nutrition), shows the immense value of dried potatos as a food. They contain almost as high a percentage of albumen as either oats or rye meal, and in composition mostly resemble maize, which they can almost entirely replace—an advantage for Germany, as all the maize used has to be imported.

Among the pre-war uses of potato flour (in this country) may be mentioned its use in the manufacture of Soup Powders (Desiccated Soups), and in the manufacture of pressed yeast, etc.

Economics.

In this country experience has indicated the acreage of land generally sufficient in normal years to produce potatos to satisfy our needs for human consumption, and no attempt is made to produce more. Such is not the case in Germany, where potato growing occupies a special position, so that in comparing the Potato Drying Industry there with that in this country, from a financial point of view, this different aspect must always be borne in mind.

The German system of agriculture aims at planting the maximum acreage of land possible to potatos, and when in abundant seasons

there is a glut on the market, attention is not directed to ways and means of reducing the acreage under cultivation, but to finding a new outlet for the surplus crops. By considerations such as these the potato growing industry in Germany has developed, and there have sprung up numerous factories for dealing with the surplus.

The cost of drying potatos depends on several factors—such as the cost of the factory, its size and situation, the price of raw material, working period, the costs of labour, fuel, etc. The size of the factory is very important. Too small a plant is worked at a relatively high expenditure, whilst a much larger apparatus, by reducing the cost of labour and making better use of fuel, etc., costs in proportion much less to work. The smaller factories, however, which are usually worked in conjunction with a distillery, a Starch or Sugar Factory, or a Dairy, can be run the most economically.

The success or failure of a Potato Drying Factory is largely influenced by the amount of raw potatos available in the district, and to ensure a constant supply the majority of the factories in Germany are run on Co-operative lines. The farmers in the combine bind themselves to supply at least 40,000 Zentner (2,000 tons approximately), though several factories erected about 1911 guaranteed 100,000 Zentner (5,000 tons approximately). It would be impossible to make proper use of the factory if a sufficient supply of locally grown potatos was not forthcoming; if the potatos to be dried had to be conveyed from any considerable distance, the price of the raw material would be too high to permit of dried potatos being manufactured at a profit. The best financial results are obtained where the manufacture is continued without interruption, or, as mentioned above, where the drying factory is worked in conjunction with other undertakings such as breweries, dairies, etc.

The technical development of potato drying has reached a very high degree of perfection in Germany. The improvements in technique during the last few years and the consequent lessening of the amount of fuel, etc., required, have been very marked.

Working Costs.—An author is always anxious to give up-to-date information, yet in these days when prices fluctuate so rapidly as to be almost useless before the information can be printed, it may be preferable to go back to times when National Exchanges were less chaotic and prices more stable. Thus, figures for pre-war years are considered where possible. The working costs stated in an article written by Professor E. Parow, of the Institute for the Fermentation and Starch Industries in Berlin, in 1913, are $3\frac{3}{4}$d. and $5\frac{1}{2}$d. per 100 lb. raw potatos, which works out at 7s. and 10s. 3d. per ton for drying. According to the water content of the potatos it requires $3\frac{1}{2}$ to 4 tons of raw potatos to produce 1 ton of dried potatos. Taking it at the higher ratio of 4 tons, the manufacturing costs to produce one

ton of dried potatos would be 28s. and 41s. With the cost of fresh potatos at 30s. 6d. per ton (approx.), the total costs (raw material plus manufacturing costs) would work out at £7 10s. and £8 3s. per ton for the finished product, viz., one ton dried potatos.

Even at this comparatively low figure, the price was considered too high in comparison with other food stuffs for stock purposes, and the matter aroused a heated discussion in the German Press at the time.

Feeding Value.—Kellner places the value of dry potatos at 100, and according to his results barley is equal to 97, and oats to 95. Their values, based on the amount of starchy food they contain, is as follows :—

Dry Potatos	68.8
Barley-food	66.6
Oats	59.6

According to Kellner's results, therefore, as regards dietetic value and percentage of starch, dried potatos take the first place, and ought to command the same price as barley food (good quality) or oats.

Barley in June 1910, 1st quality cost £8 10s. per ton (approx.)
2nd ,, ,, £8 ,,
3rd ,, ,, £7 5s. ,,

Oats, in June 1910, cost £8 to £8 10s. 6d. per ton (approx.)

The price of Dry Potatos — varying between £7 and £8 per ton about the same date—was lower, that is if we reckon the money value of a ton of dried potatos according to the starch value theory of Kellner. It is clear, however, that the Germans had in mind the replacement of imported maize by dried potatos, a home-grown product, and by means of extensive propaganda the best case was made out for the potato. The author imagines that farmers in the neighbourhood of the factories used a good deal of these dried potatos, but it is doubtful if they really did become a very serious competitor to the more popular feeding stuffs.

In England, where the position is substantially different, there is a tendency to use the readiest and most suitable feeding stuffs, without enquiry as to the source of origin, or place of production.

If, however, a Potato Drying Industry for cattle food stuffs were established in this country and assuming that our home manufacturers had reached a high standard of efficiency and skill, both in regard to the drying process and the reduction to a minimum of the working expenses, the product might find a market at the cattle food rate of possibly £10 per ton, certainly not more. The drying costs could not be less than 15s. per ton (10s. 3d. in Germany in 1913), so that 4 tons of raw material would cost £3 to dry (during

1918 the cost was £19 in Rochester), leaving a balance of £7 to be divided between transport charges and raw material. At this rate the grower would get little for his 4 tons of potatos, which in these days must have cost considerably more to produce. Such is the position for dried potatos.

II.—Potato Starch.

Starch is a white, glistening, tasteless carbohydrate, found in the form of small granules to a greater or less extent in the cells of all living plants, with the exception of the fungi, though the extent to which it enters into the composition of the plant varies considerably. Fruit, for example, contains little or no starch, whilst potato tubers, maize, cereals, and the sweet potato, contain a high percentage. All such plants are of potential use to the Starch Manufacturer, though the ones that will be used by him will depend on certain factors influenced by localities, amount of raw material available, cost of raw material, etc. In Europe starch is principally made from potatos, rice, wheat and maize. In America it is principally produced from maize with a small proportion from potatos and wheat. Japan uses sweet potatos, while tropical plants yield sago starch, arrowroot and tapioca. One interesting fact is that each kind of plant yields a starch the granules of which have their own characteristic form and special markings, so that mixture or adulteration can be detected by microscopical examination. The only starch with which this paper is concerned primarily is that prepared from the potato.

Potato starch, commonly called and sold on the market as "Potato Flour or Farina," correctly speaking is not a flour at all, but is composed almost entirely of pure starch grains. Potato starch granules have a charcteristic mussel-like appearance, are variable in size, but when fully developed they are the largest of all the starch grains.

Industry.—Although in this country, previous to the war, very little was known of the industrial uses of the potato, an industry of considerable size in starch manufacture had long before been established in Germany, France, Holland and America. Germany is the chief potato starch producing country; there the industry is chiefly carried on in small farm factories situated in country districts, where potatos are extensively grown. These small factories are usually associated with the farms, and only work during the winter months, the wastes (or by-products) from the factories being chiefly used for cattle food. In addition there are large potato starch factories in the towns, capable of producing as much as 20 tons a day, a large percentage of which is turned directly into dextrine, glucose, etc. The total extent of the German production is said to be about 300,000 tons of potato starch annually.

America stands next in importance to Germany as a starch producing country, but only 14 per cent. of the starch manufactured is made from potatos, the bulk (over 76 per cent.) being produced from maize. The total annual production of starch from potatos in the United States probably does not exceed 15,500 tons. The small, unripe, or partially diseased potatos, which are unfit for food purposes, are principally used, the result being that the starch produced is not uniform; even in the same factory the quality varies from day to day, and for certain textile purposes the American production is of little use, and a superior article has to be imported from Europe.

The production of potatos has ever been an important industry in Holland, so much so that the supply is always in excess of home requirements for direct human consumption, and there has been built up a considerable export trade to the towns of Western Germany and England. When the realised prices fall below a certain level the potatos are sent into the "potato meal" factories for manufacture into starch. President, Thorbeck, Rigenheimers and Red Star are the principal varieties used for this purpose, and generally fen-land grown in the province of Groningen. The factories which are situated in the potato growing areas generally belong to the Growers' Association and are run on Co-operative lines. It is estimated that about 32,000 tons of potato starch is usually made per year.

During the war in this country a shortage of potato starch, which had formerly been imported from Holland, Germany and America, was being experienced and the Textile Industry was in difficulties, as potato starch or farina is a necessary article in the textile trade, where it is used for dressing and finishing cotton cloth, and the war had stopped the necessary supplies. These facts led to the foundation of the potato starch industry in this country, when factories were erected in the potato growing districts in the East of England, by a firm known as the British Farina Mills, Ltd. During the later stages of the war, the British Farina Mills, Ltd., were able, after some months, to produce farina of as good quality as the German product, and in sufficient quantity to replace the supply formerly imported from Germany.

Potatos suitable for Starch Making.—In studying the question of potato starch manufacture, it will at once be seen how important a factor is the percentage of starch in the tubers to be used for this purpose, though the size of the individual starch grains is also of considerable importance. But the yield of starch per acre is the most important factor of all, and the varieties of potatos which will produce the most starch to the acre are therefore the most valuable for this purpose. It will be both interesting and instructive to give

a table comparing the various merits of the many varieties of potatos.

TABLE.

*Variety.	Starch Content.	Average crop capacity. Tons per acre.	Yield of starch per acre.
	Per cent.	Tons. cwts.	Tons.
Irish Queen	20·25	10 8	2·187
Bobbie Burns	18·5	11 13	2·155
Duchess of Cornwall	17·5	11 14	2·047
President	19·25	10 9	2·01
Up-to-date	16·5	12 1	1·988
Arran Chief	14·8	12 8	1·835
Shamrock	16·75	10 18	1·826
Beauty of Bute	22·	10 3	1·807
Champion	17·4	10 6	1·792
Abundance	17·75	9 19	1·766
Langworthy	20·5	8 11	1·753
Black Skerry	19·75	8 9	1·669
Factor	14·5	11 4	1·624
King Edward VII.	18·5	8 12	1·590
British Queen	15·25	10 7	1·578
Invincible	12·	11 15	1·410
Royal Kidney	15·75	8 14	1·370
Leinster Wonder	13·3	9 2	1·210
Champion II.	12·75	9 6	1·186

The early workers obtained the percentage of starch by chemical analysis—a somewhat complicated operation. An analysis can only be made on a sample, and the amount of starch varies throughout the tuber (*i.e.* from the middle to the outside). It has now been shown that the percentage of starch present has a direct relationship to the density. For all practical purposes, however, it is sufficient to calculate the starch percentage from the density, and this can quickly and readily be determined by the usual physical processes.

Starch Granules.—The amount of starch present is not the only factor influencing the value of any one variety, the size of the individual grains, by having a direct bearing on the quality of the starch, is almost of equal importance. The plant cells in young potatos contain a very watery protoplasmic matrix, in which there exist but a few small immature starch grains. These starch granules, at first small and soft, develop with age, and their numbers in the matrix steadily increases, so that in any one potato there are always present starch grains of different ages and sizes, and in many stages of development. A potato with a high starch content is valuable to

* From Reports of the Department of Agriculture and Technical Instruction for Ireland.

the starch manufacturer, but its value is considerably enhanced if it contains a high percentage of large sized starch grains, and this for two reasons, viz.: (1) the amount of starch extracted from the potato pulp by the technical process depends to a certain degree on the size and weight of the individual starch grains, as the larger and heavier the grain the more certainty of it being washed out, and (2) the larger the starch grains in a potato the better the quality of the "prima" starch.

Process.—The process of potato starch manufacture is a very simple mechanical one. The method consists in crushing or grinding the potatos, so as to break up their cellular structure and liberate the starch grains from the potato cells. The starch is then washed out by a process of flooding with water and decanting several times, until finally, after being dried and dressed, the finished production, in the form of a fine white flour, appears on the market as the "Farina" of commerce.

The pulp left in the sieves after the extraction of the starch usually contains 10% to 20% of the total amount of starch originally in the potato. It also contains cellulose fibre, nitrogenous substances and ash. The pulp when dried makes a suitable food for cattle. The juice from the pulp and the waste waters are rich in nitrogen, potassium and phosphorus, and the ever resourceful German makes use of these as a manure for the land.

This gives a short history of the way the German farmer has turned his surplus crop to advantage. Producing "farina" for sale, and from the by-products securing food for cattle, and liquid manure for his farm.

Uses of Potato Starch (*Farina*).—Farina is chiefly used in connection with the textile industry, for sizing yarns and for finishing purposes, though large quantities are also utilised in the manufacture of glucose, dextrine (which is also used in the textile industry) and of various gums and products of a like nature and as food adulterants. Glucose and dextrine plants are mostly run in connection with potato starch factories, and any surplus "farina" left unsold (or if of inferior quality) can be used up in the dextrine and glucose factories.

In the textile industry potato starch itself is used in the manufacture of woven materials for two distinct purposes.

1. As a size for warp yarn (thread) before it is woven.
2. For finishing woven materials and also for weighting cotton fabrics after weaving.

Before weaving all yarns must be prepared by sizing in order to make the threads finer and more wiry. The more pliable the thread the smoother will be the woven cloth, and one of the secrets of good weaving is the adequate preparation of the threads before they go

to the loom. Of all the uses of potato starch this is the most important. In spite of the higher price of potato starch in America (50 to 100 per cent. higher in 1900) as compared with maize starch, and even admitting that the latter starch will give a stiffer paste, it is claimed for potato starch that it is better for sizing purposes and especially so in the case of fine yarns. Potato starch gives a more elastic size, is thinner and penetrates better, and consequently does not dust off so easily as maize starch.

In regard to finishing, the particular kind of starch used for this purpose does not seem to be so important. In Europe, potato starch being the cheapest on the market must be extensively used both for the sizing of the yarn and for the finishing and weighting of the woven fabric, but in America it appears that very little potato starch is used for finishing purposes, and by far the most important of its uses there is the sizing of warp threads.

The preparation of starch for sizing and finishing consists in first mixing the potato starch with the proper amount of water and afterwards cooking it by heating with steam under pressure. The starch mixture is boiled from ten minutes to one hour or more, according to requirement, and after straining it is ready for use.

Potato starch is the cheapest starch sold in this country, and consequently is largely used for laundry purposes. Starch glazes are made by adding borax, finely powdered stearic acid, or paraffin to potato starch.

Economics.

Owing to the nature of its origin—starch being the most abundant substance present in the plant kingdom with the exception of cellulose —there must be considerable competition in the world's market, not only between the starches derived from the various plants, but also between the different countries producing them. Thus potato starch, rice starch, sago and tapioca starch, and maize starch compete on the world's markets and the merits of each one needs special consideration—and also the quantities of each that are imported for use in this country—but space does not permit of their being dealt with in detail. As to supplies they are influenced by the demands of the textile industry.

The textile industry is one of Britain's great industries, and yet for the starch, dextrine and sizes that are necessary to allow it to function, this industry has in the past been dependent for supplies on Germany and America. The exact extent of our dependence it is difficult to determine, because for some unexplained reason farina imports have been classified with flour and our home figures give no indication of the quantities of farina imported. German and

American statistics show that their exports to England have been as follows :—

Year.	From America. Tons.	From Germany. Tons.	Total. Tons.
1890*	1,000	24,950	25,950
1891	3,600	6,750	10,350
1892	5,900	6,750	12,650
1893	6,600	12,500	19,100
1894	—	15,900	15,900
1910	5,000	15,000	20,000

In addition smaller quantities are imported from Holland and Japan, and sago and farina from Java and Singapore. In 1894, for instance, some 34,600 tons were imported into England almost exclusively from the Straits Settlements. At Paisley, in Scotland, there is a Scotch starch industry where American maize is used for the preparation of starch for the textile and kindred industries, but the author has no figures to show the extent of this production.

That the British requirements in starch, and especially potato starch, is large, is indicated by the above figures, and it is apparent that three different kinds of raw materials are used in the manufacture :—The tapioca or cassava of the Straits Settlements, the maize of America, and the potato of Germany and Holland. Competition is keen, and prices have been kept at a fairly low level. The author has been fortunate in being able to reproduce figures showing the prices for the various articles which were on sale at Manchester in November, 1894, and these prices kept about this level for years.

Kind of Starch.	Price per Ton. £ s. d.
German Potato Starch	10 0 0
Dutch „ „	9 8 0
American „ „	10 10 0
Scotch „ „	10 0 0
Tapioca Starch	9 12 0
Sago „	7 4 0

During the war supplies fell, in many instances being completely cut off, and prices rose as high as £36 per ton. Some recovery of the industry has since been made, but the production in Holland and Germany is still less than normal. Supplies are less plentiful and the competition less keen, so that the ruling price in the English markets is now about £27 to £28 per ton. Keeping these figures in mind it is

* "These figures relate to 'farina,' the manufactured products from Germany and America are not included."

possible to see what the British farmer could expect for his potatos, if utilised at the present time in the home factories for the production of starch.

Cost of Production.—To arrive at any accurate figures it is necessary to consider the cost of production (pre-war), and the only accurate figures available are those relating to the German Industry for German Factories. Average figures for these show that the cost of working 100 cwt. of German potatos having 18 per cent. of starch contents would be as follows :—

Pre-War Prices.

	£	s.	d.
100 cwts. potatos would yield 17·1 cwts. dry starch of which 85 per cent. or 14·5 cwts. is prime. Valued 10s. per cwt.	7	10	0
Value of by-products, 2·5 cwts. at 6s.	0	15	0
Plus pulp value (for pig food)	0	4	0
Total	8	9	0
*Less Working costs, 5 tons	2	0	0
	6	9	0

In other words the value of the 5 ton potatos would be £6 9s. or £1 6s. per ton, and this represents the sum that would be returned to the grower for his potatos.

The present price of farina is £1 7s. per cwt., and the working cost (labour, fuel, etc.), must have increased by at least 100 per cent., so that the figures relating to the present manufacture would be :—

	£	s.	d.
100 cwts. potatos produce 14·5 cwts. prime starch valued at 27s. per cwt.	19	11	6
Value of by-products, 2·5 cwts. at 10s.	1	5	0
Pulp value	0	6	0
Total	21	2	6
*Less working costs for 5 ton potatos	4	0	0
	17	2	6

That is, the farmer's 5 ton potatos would be worth £17 2s. 6d., when converted into starch, or £3 8s. 6d. per ton.

This price per ton is not high, but potatos have been sold in this country for considerably less. Since then land has increased in value, wages have gone up in price and also manures and machinery, so that the cost of production has now reached a high figure. The question, however, as to whether potatos can be produced at a profit in this country for £3 8s. 6d. per ton, is one outside the scope

* The working costs stated above are said to include manufacturing profits, establishment charges, etc.

of this paper. Even though they cannot be produced for this amount it might be wise on the part of any Government to foster such an industry, so essential to the Textile Industry, and so useful to encourage an Agricultural Policy; or it might be considered a shrewd scheme for the growers organisations to keep such factories running, as a means for dealing with surplus crops. It must always be borne in mind that the present price of "farina" will not be maintained when production again becomes normal.

III.—Alcohol.

Alcohol is produced by the fermentation of sugar and there are almost innumerable sources for its manufacture. It can be produced from all substances containing fermentable sugar, or from starchy substances which can be converted into fermentable sugar. Alcohol can therefore be obtained in practically unlimited quantities from a great variety of plants grown in every kind of soil and in all climates, for sunshine, air, and water alone are necessary for the development of the materials required as the source of alcohol. But although starch and sugar are found in most plants, it is only those plants, which contain a high percentage of either of these substances which can be considered suitable for the commercial production of alcohol; certain fruits, for example, contain such a small percentage of sugar that it would not pay to work them. Whilst in this country barley and wheat are almost entirely used for distilling purposes, potatoes are now the principal source of alcohol in Germany, and the history of the development of the industry is interesting.

The Potato Distilling Industry must naturally be of recent origin since the potato has not long been extensively cultivated in Europe. Germany must, however, have lost but little time, since the first potato distillery is said to have been started about the year 1750, at Monsheim in the Palatinate, though it was some eighty or ninety years later before the industry really developed. It would be difficult indeed to sift out the factor or factors which made this development possible, but so far as can be judged by the writings in existence, the way for the development was made easier through the German general policy for the protection of Home Industries, in which agriculture is included.

The light sandy wastes of Eastern Germany are of little use except for potatos, and potatos are a potential material for the manufacture of Cattle Feeding Stuffs, and Alcohol. The former replace maize and the latter petroleum oils—both of which Germany had to import from other countries. In fostering the Potato Distilling Industry, German Agriculture was greatly stimulated, and the light classes of soil were turned to advantage, prime industries were developed and imports lessened. The close association between

this industry and agriculture is a pleasing but remarkable incident. Potato Alcohol Manufacture even now is not run as a separate unit, but is almost entirely joined up with the farms and might almost be considered as part of the agricultural industry and the distilleries might be mainly regarded as Agricultural Distilleries.

In Eastern Germany there exist vast tracts of light sandy soil of little use for grass or cereal production, but by continuous cultivation and judicious manuring they have been rendered fertile for the cultivation of potatos. As the potato area developed, and the crops increased, there arose the difficulty of dealing with the large crop not needed for direct consumption. Necessity is the mother of invention. In this case the invention, or rather the creation, was the Agricultural Distilleries on the farms for the purpose of turning surplus potatos into a saleable article. These distilleries were by no means of the same size. At the commencement they were but farm stills. The cost of running these small distilleries was considerable, and there were other drawbacks. The men on the farm, who work the small distilleries, have neither the knowledge nor the necessary technical skill to operate the whole process, and this means a loss of efficiency, a high cost of production, and an inferior product. Further, the small farm distilleries by only dealing with the surplus on one farm—which was seldom large—rarely worked continuously, and so plant was lying idle. Co-operation on the part of the farmers was needed and this movement soon grew. The small farmers united together, larger distilleries were built, and the farmers, separately and collectively, pledged themselves to keep these supplied with material and to run the industry on co-operative lines.

Success attended their efforts; larger areas of potatos were cultivated, and more alcohol was produced. The size of the industry and the rate at which production increased is well illustrated by the figures in the following table, which show the amount of absolute alcohol produced in Germany in the years indicated:—

Year.	Quantity.
1855	32,757,700 galls.
1860	42,003,825 „
1865	52,570,825 „
1897	79,252,000 „
1901	112,010,000 „
1905	115,444,475 „

Waste Products.—This was not the only gain to the farmers. In manufacturing alcohol from the potato, nothing but the starch is used up. The protein, oils, etc., are unimpaired, so that the mash or pulp serves as a useful food for cattle, which it was necessary to

maintain to provide manure for the light sandy soils. The farmer thus manufactured alcohol and produced cattle for sale, and for the production of both he depended largely on the potato crop.

Selling the Alcohol.—In the production of the alcohol the farmers had been more successful than with the marketing. The price paid to the distillers was fixed early in the season by the Chamber of Commerce in Berlin. The prices paid were by no means high, yet when the alcohol got into the hands of the dealers, they invariably advanced, and large profits were made. This gave rise to dissatisfaction among the distillers, who therefore combined to protect themselves by co-operation in the disposal of the alcohol they produced. The Society of German Distillers (mostly composed of agriculturists) eventually arranged to turn over all the alcohol manufactured in their distilleries to the Central Association (organised in 1898), which was to dispose of it to the best possible advantage for the distillers.

This arrangement was very successful, as the Central Association, in addition to marketing the alcohol, did good propaganda work towards increasing the consumption of alcohol for technical purposes, as seen by the following figures :—

Year.	Industrial Alcohol.
1898	23,511,575 galls.
1899	26,153,325 ,,
1905	39,097,900 ,,

Taxation.—Alcohol whenever produced is always subject to taxation, and the industry in Germany has proved no exception to the general rule. At the commencement there was a tax levied on each still, but in 1820 the Government changed the system of taxation, and replaced the tax on the still by a tax known as the "Mash Capacity Tax," *i.e.*, a tax on the size of the vat. This tax helped greatly in the development of the industry, as it was to the advantage of the distiller to produce the maximum amount of alcohol from the mash. Such stimulus leads to improved methods of technique, and the use of varieties of potatos of high starch contents.

In 1887 additional taxes on the finished product were levied, but it was so arranged that the burden was thrown on the alcohol used for consumption, leaving industrial alcohol tax free. This preferential treatment was to the good, but it evidently did not encourage the use of industrial alcohol as fast as it was produced, and fresh measures were necessary, so that in 1895 a new Distillation Tax was imposed. The revenue from this tax was used as a bonus to cheapen the price of alcohol for industrial purposes (*i.e.*, alcohol for other than beverage purposes used within the German boundaries). Thus we read in the report of the Departmental Committee on Industrial Alcohol that, in 1903, there was collected from the taxes on spirits a total

sum of £10,000,000, out of which sum a of £3,100,000 was given back to persons interested in the trade in industrial alcohol.

Such returned sums of money could be spent in one of three ways: (1) to decrease the price of the alcohol to the industries; (2) to lower the cost of production; and (3) to be returned to the grower as a subsidy on his potatoes. In practice in most years a portion of the money is probably devoted to each; the sum total being that the production of the alcohol is stimulated, though many may read into this that a Government subsidy is given to the industry. The producer of the alcohol does certainly receive a bounty on some of his alcohol from the Government, but it is only a portion of money which has been raised in taxes within the industry itself. The bounty returned could only be secured for a certain limited output and in this way the bounty provided within itself an arrest of the stimulus after a certain quantity had been produced. Germany was only anxious to produce sufficient to satisfy the demand for consumption for all purposes within the protected German market. In 1909 the Mash Capacity taxes gave way to a fresh method, where the amount of duty varied with the size of the distillery—the more the output the higher the grade of taxation. Such a taxation gave a great advantage to the small agricultural distilleries, and the Germans clearly intend this for the protection of the Agricultural Industry.

Excise.—Taxation naturally leads to excise control. The system of excise control in Germany does not require the constant attendance of excise officers, and consists of:—

1. Mechanical Contrivances.
2. Book Entries.
3. Liability to Visitation.

The Mechanical Contrivances do not provide security against abstraction of mash from the fermenting vats, though these are gauged and the plumbing of all joints of the pipes leading from the vats to the still are under Revenue seal. But from the point when, after fermentation, the mash is passed into the still, every vessel is locked and sealed, and no access to the spirit can be obtained by the distiller. In the larger distilleries the meter records the amount of spirits distilled, but it is an expensive piece of apparatus, and in the smaller distilleries it is dispensed with, as in any case the receiver is under lock and key, and the quantity of spirits can be ascertained from it.

The Book Entries.—The chief importance attached to the book entries is in regard to the times of charging and discharging the fermenting vats, and the quantities of mash in each, but these entries can always be checked by the amount of spirits found in the receiver.

Liability to Visitation.—Visitation at irregular and frequent intervals is one of the essential features of the system of control. It, however,

is lenient and rests heavily upon confidence on both sides, so that together with a low duty on spirits, and a system of rebates, the Excise may even become a source of profit to the small farm distiller.

Uses. — Apart from consumption as a beverage there are three chief purposes for which alcohol is used : (*a*) Domestic use, such as for lighting, heating and cooking. Its suitability for heating purposes is well known in this country, and its high price only prevents its more extensive use. It is equally as satisfactory as paraffin for lighting purposes, provided it is burnt in special lamps. (*b*) Engine use. In internal combustion engines and with suitable alterations in mechanism it is possible to use alcohol. By taking advantage of this, Germany has been able to use a home product for running the farm engine and for driving the war motor cars. (*c*) Chemical or industrial purposes. For these purposes there is a huge field for the use of alcohol. In the preparation of coal tar dyes, smokeless gunpowder, vinegar, ether, artificial silk, lacquers and varnishes, one of the essential items is a plentiful and cheap supply of alcohol. This is sufficient to illustrate the wide range of purposes to which alcohol can be put, and to remove the doubts of those who feel that the demand for it would not be large.

Economies.—It is admitted that the price must be cheap. For lighting and heating purposes alcohol would have to compete with ordinary paraffin and for use in internal combustion engines with petrol. For chemical or industrial purposes there would be no competition, and the country which could produce the alcohol cheapest could start with a great advantage, for it must be remembered that the numbers of raw material from which alcohol can be produced are many. Alcohol produced from maize, wheat, or barley, would compete with alcohol from potatos, and in this way the world's price is kept low. The immediate problem with which the author is primarily concerned is the price which potatos would be worth if turned into alcohol. No statistics on which one could rely are available for the cost of production in Germany for any years, but it does appear that farmers as a general rule did not in pre-war years receive more than £1 5s. per ton for their potatos — the average being nearer £1. These figures do not take into consideration the farmers' proportion of the State bonus, returned to them as distillers in accordance with the arrangement of the Distillation Tax. The amount received from the bonus would, in most instances, be less than 20s. per ton of potatos used. At these prices proof alcohol was sold roughly at 1s. per gallon, as compared with petroleum at 5d. to 7d.

In America the figures relating to the production of alcohol from potatos, in 1910, showed that for this purpose potatos were worth but 23s. 4d. per ton. These figures are only slightly higher than the German ones, and it may then be assumed that in pre-war years

20s. to 25s. per ton was the value of potatos if used for alcohol production, though, of course, it must be remembered that the spent mash is of some value to the farmer for feeding purposes.

Prices of alcohol have increased and also costs of production, and though the farmer might now possibly receive back £2 to £2 10s. per ton for his potatos, his expenses would also have correspondingly increased. Experts in distillation have repeatedly stated that alcohol can be more cheaply produced in this country from maize and cereals than from potatos, and the few figures available support their statements.

Conclusion.

Reviewing then the whole position it does not appear that in this country, which has for many years adhered to the great Free Trade policy, and freely opened the home markets to the world's supplies, the farmers can hope to secure any material financial gain by growing potatos specially for the manufacture of dried potatos, farina or alcohol. Nor does it appear that they would receive higher prices for their "chats," diseased tubers, or the surplus crop, by manufacturing them instead of feeding them raw as at present to pigs. All the facts and figures advanced prove the reverse to be the case. An industry of this kind only appears possible in a country where protection has been accepted as the National Policy. Germany presumably at the commencement started this industry as part of her great Agricultural Policy of keeping the maximum extent of land under the plough, and to have a big population engaged in rural pursuits. This policy has been persistently followed throughout. The German industry at all stages has been encouraged, fostered and protected. The manufactured dried potatos have been encouraged by extensive Government propaganda to take the place of imported maize; the potato starch industry has been rendered secure by making it a financial impossibility for any other country to send starch into Germany at a profit; the alcohol for light and heating purposes has been given an advantage seeing that the price of paraffin has been kept up by a tariff duty of 2½d. per gallon. In transit, alcohol secures the further advantage over paraffin in enjoying preferential railway rates. It does not appear that such protection has led to any increase in the price of potatos used for food—rather the reverse. The acreage of potatos is very large in Germany, and as the supply is always in excess of the demand for human consumption, the price has in virtue of competition been kept low and fairly stable. In pre-war years £4 per ton was usually the market price.

The adoption in this country of a progressive policy as regards the potato crop would have far-reaching effects. Much of the land now being put back to grass could be kept under the plough: much

of the sandy soils and the fen soils would be improved and kept in a high state of cultivation if the acreage of potatos were increased. Besides, in the cultivation of the potato crop much labour is required, and any movement that would help to solve the unemployment problem at the present time would be helpful. Before any increase in the present acreage is possible, it would be necessary to make adequate arrangements for using the surplus for industrial purposes. Dried potatos do not appear to have many advantages, and it is unlikely that such an industry, if established, would maintain itself for long. Owing to the high rate of taxation on alcohol existing in this country and the excise restrictions regarding its manufacture in small quantities on numerous farms, it would of necessity be so costly and troublesome as to operate against the production of a cheap spirit and against securing the good-will of the British farmer in building up and extending an industry which would of necessity be so hampered and controlled.

In the case of potato starch the facts set out have shown the position to be entirely different. The textile industry for its proper working must have plentiful supplies of starch, and preferably potato starch, which up to the present have been principally supplied by other countries. There is no reason to fear that these supplies would not be forthcoming in normal years under peace conditions, but in times of war with the consequent submarine warfare and blockades, supplies might be completely cut off and the textile Industry brought to a standstill. This is an additional and valid reason why efforts should be made to establish a starch industry in this country. Its development would help to keep going the agricultural "plough" policy, to encourage the employment of more labour on the land, and to put the textile industry in a safe position. For this reason the potato starch industry might well be regarded as a "Key Industry." If this were possible and an industry could be established, it would be possible to increase with safety the acreage of land under potatos by about forty to fifty thousand acres. This increase would make the country self-supporting for all potatos other than earlies, and in view of the fact that supplies would be heavier, market prices would tend to be more stable and so operate to the general advantage of the consumer.

Finally the author would like to record his great indebtedness to Miss A. D. Mackenzie, of the Ministry of Agriculture, for her kind and generous assistance and co-operation in the preparation of this paper.

Lord Bledisloe invited discussion and said that with Government encouragement he thought progress might be made along the lines suggested by Mr. Taylor's comprehensive and well-reasoned paper.

SIR LAWRENCE WEAVER said that during the war attempts at making "farina" had failed financially since the price at which it could be put upon the market did not give a fair return to the grower. Both he and PROF. CAMPBELL (Ireland) commented upon the fact that these experiments had been made in quite abnormal times and PROF. CAMPBELL thought it would be well to investigate the problem again in more normal conditions. He questioned whether the varieties commonly grown were those best suited for starch production and looked upon the potato as a valuable aid to the food supply, especially when used for the production of pork.

DR. QUANJER (Holland) stated that before the war, Holland had manufactured and exported farina in large quantities, but that Japan was now producing it so cheaply that Holland had been driven out of the trade.

DEGENERATION OF POTATOS.

By REDCLIFFE N. SALAMAN, M.D.

THE subject of this paper has proved a source of interest to students of the potato for fully 150 years, and it is only in late years that opinion is becoming more settled in respect to it.

The earliest, as the latest, contributions to this subject have ranged themselves round two points of view, the one that degeneration is synonymous with senility, the other that it is but a manifestation of one or another disease. The point of view which is here put forward is in accordance with the latter of these two explanations, a conclusion which has gradually become more insistent as my knowledge of the potato, and my experience thereon, have grown.

Although many of the earliest observations of this problem emanated from English writers, we owe the more recent work to French and German authors.

Very recently Ducomet (4) has published a most valuable paper on this subject in which not only the history of the controversy is sketched, but a brave attempt is made to place the issue on a logical foundation. It is not my intention to go over the ground which Ducomet has traversed, except in so far as it may be necessary to make my contention clear, but rather to add new evidence to his. Nearly all writers before Ducomet have failed, in the first place, to define what they mean by degeneration, and, in the second, to keep clear the distinction between changes which might be ascribed to senility and those which might be ascribed to disease. All the authors seem agreed that degeneration is evidenced primarily by decrease in capacity for cropping, and associated with this decrease are described symptoms such as the crinkling and rugosity of the leaves, dwarfing of the

plants, and an increasing rigidity or brittleness of all parts of the haulm.

Such symptoms as those described recall to our minds at once those well-known conditions which are described under the names of "Curl," "Mosaic," "la Frisolée" and "Krauselkrankheit." It is clear that at a very early date in the history of the cultivation of the potato, growers were confronted with a condition which, affecting their plants, had as a result the reduction of crop, and, futher, it was early recognised that this deterioration affected certain varieties and became increasingly severe in successive years. Nor was it long before it was realised that some varieties, at any rate, in certain districts, escaped, while others fell. Thus in 1795 it was noted that *Surinam* did not suffer the change which affected other varieties, and, indeed, we have this very variety growing to-day.

The first authority who took a definite point of view in respect to the degeneration of the potato was Parmentier (17), who, in 1786, discussed the problem at full length and came to the conclusion that the trouble was due to repeated vegetative reproduction which, Parmentier explains, acts as a dilutant of the genetic force contained in the plant which sprang from the original seed; and he goes further and locates the trouble, asserting that it arises from the introduction of potatos from Ireland, where they had been already grown for 100 years.

It is interesting to find that so early as 1795 Dr. John Anderson (2), without making reference to Parmentier's views, takes an exactly contrary standpoint. He says: "I have never met with a single fact well authenticated that tended to show that any kind of potato really degenerated by a continued cultivation for a length of time further than what can be easily referred to the cause above explained." And when we refer to this cause, we are met with a very extraordinary anticipation of modern views. Anderson complains that the potatos of his time were extremely mixed and states that "raisers are in the habit of mixing the produce from several seedlings, hence the mixture of sorts, and owing to propagation from small sets of this mixed stock, the best and prolific varieties get eliminated." It is obvious that Anderson had in his mind the idea that the degenerative change which is complained of is a varietal feature.

Andrew Knight took an opposite view. In 1818 he asserted that each individual has a capacity to live to a certain age; that passed, it dies. It can remain whole or it can split up into different individuals by budding or grafting. And in 1833 (13) he pronounces definitely in favour of degeneration due to senility. "The fact that every variety of potato when it has been propagated from part of its tuberous roots becomes less productive is, I believe, unquestionable." "I have often witnessed the progressive decay of vigour and the

different effects of the influence of age upon many different varieties. The quality of some has remained perfectly good after the produce and quantity has become highly defective, whilst in others that has disappeared with the vigour of the plant."

Phillips (20), in 1822, says: "It has now become a question of great importance and one which deserves the most serious investigation, whether this root now justly styled the bread fruit of Great Britain and Ireland degenerates or loses any of its good qualities by the long continued practice of raising it from eyes."

Aitken (1), in 1837, developed the theory of senility in respect to the potato, ascribing the degeneration to continued tuber propagation, and thought the first sign of such degeneration was a failure to produce blossom. This view was accepted widely, being strongly supported in Germany by Heine (12) so late as 1884-1891.

How extensive was the degeneration in the potato is shown by Shireeff (25), who complains that "not a single healthy plant of any sort of potato that yields berries and which was in culture 20 years ago (i.e. before 1849) can now be produced," here further re-echoing a view he had long held, that excessive "apple" bearing is the cause of curl and old age, which he compares to the exhaustion from which all animals and plants are said to suffer who have expended their sexual force too actively.

Putsche (21), a German author who compiled a valuable monograph on the potato in 1819, speaks of curl in the same sense as other authors do of degeneration, and clearly states its transmission by tubers and the varietal incidence of the disease; and goes on to show that new and old alike fall victims to the new malady. His description of the degenerative changes due to "curl" with mottling of leaf, brittleness of haulm and reduction of crop, might be mistaken for an up-to-date picture of mosaic disaese.

Sir C. Leman (14), in 1843, describes a disease which obtained the local name of Bobbin-Joan, which would seem to have been an extreme phase of curl or mosaic, and talks of "the exhausted vitality which we know will only last a limited time after the creation of a new plant from blossom seed, though its produce be extended over an unlimited surface by the propagation of its offspring." Such "degenerated" potatos, he says, should be "regenerated" by seed.

After the great outbreak of phytopthora in 1845 the question of degeneration of the existing varieties again became acute. Graham (11) strongly declares against the idea that certain new sorts were more immune than some of the old because the latter were superannuated.

Aimé Girard (10), who performed such splendid pioneer work on selection in regard to the potato, whilst recognising the fact of degeneration, would see in it only a problem of tuber selection. The passage in

which this great authority refers to the problem deserves quotation in full :—

" There is an opinion very widely held that varieties of the potato cultivated continually in the same area, are fated to certain degeneration. It is indeed a frequent thing to hear the large potato-merchants, and notably the starch manufacturers, declare that, after having imported into their district and distributed to the cultivators varieties noted for their large crops, they have observed excellent results in the first year, but when one regards the second season the results fall away, whilst in the third year they reach a level lower than that of the varieties customarily used in the locality. The facts are certain, but it is not in any way so assured that the degeneration which one observes under these circumstances is the result of a natural degeneration of the variety. It results, indeed, solely from a lack of care with which the plant is selected. All the good tubers are sold to the mills or to the merchant, and it is from the inferior tubercles, throw-outs, that one seeks a continuation of qualities they are powerless to give.

" I hold to have demonstrated this point practically and to have established that in making a suitable choice of the tubercles of the plant, and in conducting their culture with the necessary care, one is assured of seeing the crop maintained, or at any rate it will only be decreased under adverse meteorological conditions, to rise once more in the following season when conditions are again satisfactory."

Turning now to recent writers we find that Ehrenberg (8), in 1904, after a careful analysis of available data, comes to the conclusion that in all probability there is no such thing as senility.

East (5) also is strongly opposed to the idea of degeneration or senility occurring as a result of continuous bud propagation. Recent French writers such as Perret (18 and 19), Parisot (16) and Ducomet (4) all take the view more or less strongly that the changes called degenerative are in reality the product of disease. Delacroix (3) takes up an intermediate position in regarding degenerative conditions as not due to disease in the ordinary sense but as physiological failings. On the other hand Sartory, Gratiot and Thiebaut (24) declare that degeneration is a real phenomenon and due to propagation by budding for 400 years. Quanjer (22, 23), in his recent and brilliant researches, identifies the degeneration of earlier authors with mosaic and kindred diseases, and shows that this degeneration is neither a physiological disease nor the outcome of senility, but behaves as a definite infection. The existence of two quite distinct diseases, leaf-roll and mosaic, have been clearly established, though the specific virus of neither has been isolated. So far, therefore, opinion has been steadily and increasingly tending to the view that degeneration is a morbid process rather than the outcome of senility. It is now proposed to consider the problem from a somewhat different point of view.

Assuming that the changes met with in the potato which reduce its output, dwarf its growth, deform its leaves and ultimately inhibit its existence either directly or in subsequent tuber generations, are not due to any pathological process in the strict sense of the word, then one is compelled to assume that they are due to old age—senility—or to a tuber mutation. Thus it is conceivable that a single tuber of a variety might suffer some mutational change by which its vitality was so sapped that its immediate successors would become progressively weaker. Although such might be possible, it would not account for the sudden degeneration observed in an entire crop. East's (7) work on asexual mutations in the potato demonstrates their extreme rarity, and his researches on selection of variations leads to the conclusion that little advance is to be derived by that means. Stewart (26) has likewise considered this possibility in a sympathetic spirit, but eventually rejects it. Whipple (27) who ascribes degeneration to disease, considers that it may be regarded as a "tuber character," the degree of infection being different in the various tubers of the same plant and associated with a physical change in the tuber eye which tends to become increasingly superficial. The phenomenon, however, must not be confused with that of a tuber mutation which it superficially resembles. It may be accepted therefore that degeneration is not an example of an asexual mutation.

When, however, an attempt is made to define what is meant by the term difficulties begin.

Senility—Ageing presupposes that the given organism has a certain period of life beyond which its vital force is insufficient to maintain its existence, and the individual ceases to exist; but before this stage is reached, in most cases sexually formed seed has been formed which allows for the continuity of the species. If, however, the formation of sexually formed seed allows for the continuity of the species but not the individual, the disappearance of the latter is yet guarded against by the formation of buds, shoots, layers and tubercles, by each of which the individual plant is reformed and perpetuated. The potato is an example of a plant which reproduces itself by budding by means of tubers as well as, in many varieties, producing sexually formed seed. And the question arises as to whether the individual who started life as a sexually derived seedling, and which reproduces itself annually by tubers, is endowed with a fixed term of life, during which the bud germs are only capable of a given number of consecutive divisions, or rather whether it is not, the environment being normal, virtually immortal. It is the latter view which is adopted here, and it is not only in logical accordance with this view but also with a long series of observations that I am convinced that Ducomet (4) is right when he says, "Degeneration is merely the expression of lack of adaptation to environment."

Nevertheless authors more or less competent continue to speak of the degeneration of varieties of potato, of their ageing and the like, yet they fail to parallel their phenomena with similar occurrence in other cultivated plants which reproduce asexually. Indeed, when such comparison is made, the fact is at once apparent that these at least show no evidence of senility.

To note a few instances:—The vine: many varieties still grown and prized are as old as history, and indeed legend would claim that the very grapes of Eshcol are still to be found on our tables. Some of the best varieties of apples and pears are three and four hundred years old. The banana has never been known except as an asexually produced plant, whilst the growth of the sugar-cane is likewise by means of shoots. The "Jerusalem" artichoke (Helianthus tuberosus) is a vegetable whose culture is identical with that of the potato and whose introduction into Europe was contemporary. There are but three varieties of artichokes grown, but one has never heard of their degenerating, nor of the necessity for renewing the varieties from seed. None of these plants show any signs of varietal old age or decay.

And here perhaps one may best point out one of the chief fallacies in the argument for degeneration by senility. If a variety is "degenerated," and this degeneration is due to the exhaustion produced by continued bud formation, then, as the representatives of that variety in every part of the world have in any given year been derived after exactly the same number of bud divisions, clearly the variety should show signs of decay in all parts alike. This, however, is notoriously not the case, for whilst varieties may perish miserably in a few consecutive years, in the dry and low-lying districts, they may be flourishing on the hills a few score miles away. Indeed some varieties once most popular have, like Magnum Bonum, passed out of cultivation in England because of their "degenerative" symptoms. Yet in Sweden it is this very potato which is most grown, notwithstanding that it has been in cultivation for 50 years. It would be easy to give many examples where the same potato has died out in one district and flourishes in another, a certain indication that the "degeneration" is not due to old age but to an adverse environment, whether induced by the introduction of a virus or by inauspicious climatic conditions.

It has been contended from Parmentier's time downwards that the only remedy for degeneration, whether due to senility or environment, is the creation of new seedling varieties, and the term "rejuvenation" of a variety has been used in this relation.

An experience of 16 years in the systematic breeding of the potato has impressed on the writer the following general conclusions:—

(*a*) That the very great majority of domestic potatos are hybrids of greater or lesser, generally greater, complexity, and that the selfed seedlings of such display the heterozygosity which is to be expected.

A very small percentage of such offspring may be in every respect similar to the parent, and may be said to reproduce the parent type, but inasmuch as such a seedling would have the lowest chance of being selected, it would be incorrect in the great majority of cases to speak of a variety being "rejuvenated" in the person of a chance selected seedling offspring.

(*b*) It has been the good fortune of the writer, and lately of his colleague, Mr. J. W. Lesley also, to have bred a few varieties of potato true to type, i.e., the selfed seedlings have reproduced in flower, haulm and tuber every characteristic of their parent. This has been done twice with white-flowered, prostrate-haulmed, long finger-shaped-tubered parents, and twice with white-flowered, upright, red round-tubered parents. The former parents were closely related, the latter but very distantly. Some emphasis is laid on these facts as the impossibility of breeding true from seed has been so often asserted without sufficient demonstration.* Here, then, sexual rejuvenation may be said to occur, just as it does in the identical seedlings raised by seed from the wild S. tuberosum and S. verrucosum.

(*c*) Degeneration may occur in a seedling at any age. Some seedlings are feeble from birth, and are unable to accommodate themselves to the environment, others survive one year and fail the next, and others, after enjoying a great vigour in the first year, settle down to a normal and healthy life in succeeding years.

(*d*) The degeneration which is observed in seedlings is of exactly the same nature as that seen in established varieties. The symptoms which are in reality those already described as peculiar to curl, are frequently augmented by the appearance of blotching on the leaf which confirms the existence of mosaic.

(*e*) The rapidity of onset of degenerative symptoms in the potatos raised in the author's experimental grounds at Barley, on the border of Cambridgeshire, depends almost entirely on the length of time the tubers are grown in the same locality. If seedlings are removed after the first year to Scotland, then degeneration in many cases can be avoided, but if the seedlings are grown on for a few successive years in Barley, their fate is sealed. Practically no variety or seedling can be grown on for more than two years in this district without evincing severe signs of degeneration.

(*f*) Notwithstanding what has been stated in the preceding paragraph, every now and then we find both established varieties and seedlings which will hold their own apparently indefinitely in Barley. Thus the old variety, Edgecote Purple (1883) flourishes here, and not

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* So recently as October, 1921, Mr. Martin Sutton, in a paper read at the Ormskirk Potato Conference, laid the greatest stress on the impossibility of producing pure strains of potatos.

only here, for in parts of Wiltshire it has been grown continuously in gardens for over 30 years.

Barley Bounty, a seedling raised in Barley in 1911, has grown continuously and cropped heavily in the same district ever since. Two other seedlings, one derived from a cross of Congo x Flourball, and one a selfed seedling from S. edinense, sometimes, though incorrectly, known as S. etuberosum, have grown in the Barley grounds and maintained their strength since 1907 and 1909 respectively. None of these varieties show any signs of mosaic disease or curl. They are immune, and this immunity is varietal and probably specific.

Finally, some facts will be now presented which would seem to be conclusive evidence against the view which regards degeneration as equivalent to senility. If degeneration is due to senility, then this senility must affect all the cells of the plant and more particularly those which give rise to the germ or buds of the tuber. From the "degenerated" bud rises a degenerated stem which in its turn bears flowers whose capacity to produce selfed seed is dependent, amongst other factors, on the variety. Assuming that the "degeneration" is due to senility, then the egg and pollen cells will alike be senile, and their union should give rise to a family of seedlings which would be expected to differ materially from a family derived from the same parents before the latter were degenerate.

Indeed if degeneration in potatos is to have a meaning in any sense comparable to that which it has in common usage, we should expect that the offspring of parents,* both of which have become degenerate, should themselves be branded with the stigmata of degeneration.

The hereditary cropping capacity of plants has been studied by the writer in conjunction with Mr. Lesley for many years over a series of several hundreds of families and tens of thousands of seedlings. The method employed is as follows:—

The crop of a seedling is measured both by weight and relatively. The latter is determined by placing the seedling in one of five classes:

Class 1 where the crop in relation to the haulm is very good.
" 2 " " " " " " " good to fair.
" 3 " " " " " " " poor.
" 4 " " " " " " " very small.
" 5 where there is .. .. No crop.

Such classification is obviously dependent to a great extent on the personal factor, but we have found that a curve derived from such classification made by one of us in Barley will be practically identical with that made of the same family by the other in Cambridge. Repeated trial has shown the method to be sound.

* A family derived from a "selfed" individual is equivalent to one derived from the mating of two identical parents.

The percentage of each such class in the family is then plotted out as a curve, whilst in the same manner curves representing the incidence of the weights, the vigour and the height of the plants, may be added. In this way the genetic output of a single plant or its vegetative successor can be gauged at various intervals of its career, or a comparison may be made between the cropping capacity of different varieties, or, what is more important, its relative value as a potential parent in crosses, accurately gauged.

In the course of the research on cropping,† a number of instances have occurred where the same plant has been tested twice, once when healthy and again when degenerated. Two examples are given below :

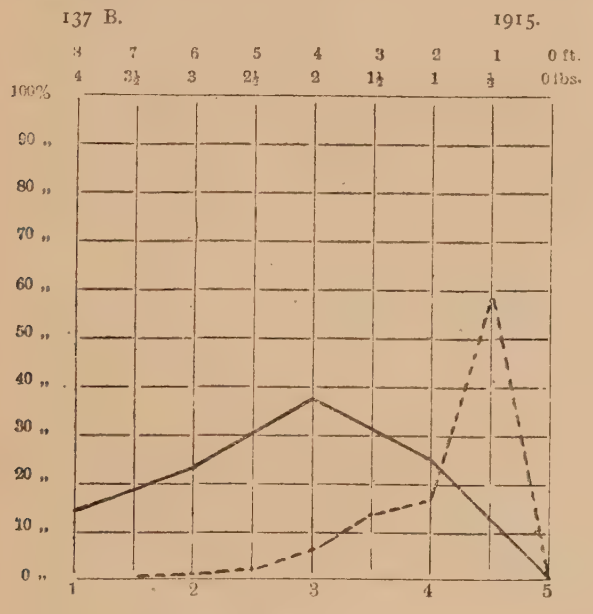

Fig. 1.

——— Cropping Curve.

..... Curve of actual weights of seedling crops.

137B is a plant raised in 1913 ; in 1914 it was healthy and set seed, the family from which is shown in Fig. 1. The plant was grown on till 1920, becoming progressively weaker. Fig. 2 represents the curve of the family raised in 1920 from 1919 seed. It will be noticed that the two curves are substantially the same in all respects.

Another example, 54B was grown in 1914 and 1915, the parent becoming progressively degenerated, and yielding itself smaller crops ; it gave, however, when selfed, curves of relative and actual cropping in 1914 and 1915, which are as nearly as possible identical. In this example it is of interest to see that 20 per cent of the seedlings in both

† It is hoped to publish the work shortly.

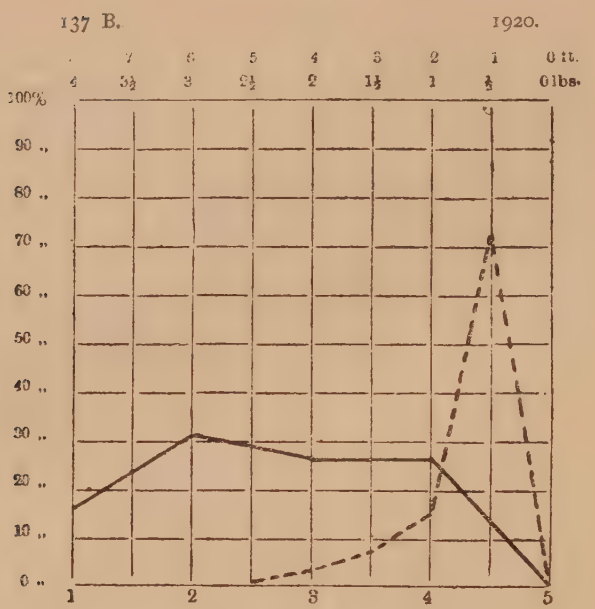

Fig. 2.

——— Cropping Curve.

..... Curve of actual weights of seedling crops.

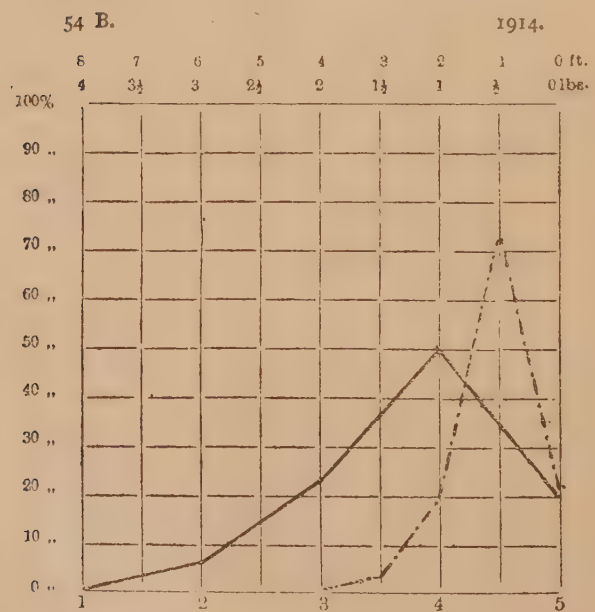

Fig. 3.

——— Cropping Curve.

..... Curve of actual weights of seedling crops.

years bore no crop at all, a property they inherited from a wild great-grandparent. Other examples could be given, but space forbids. Before, however, leaving this question of family cropping, it may be pointed out that not only are the cropping curves similar, but in general the mortality of seedlings, as measured by those that die in the first eight weeks of being planted out, is the same in selfed families derived from the same parent.

The explanation which is offered in respect to the constancy of the cropping classes in families derived from the same parent, both when healthy and when "degenerate," is that the degeneracy is not due

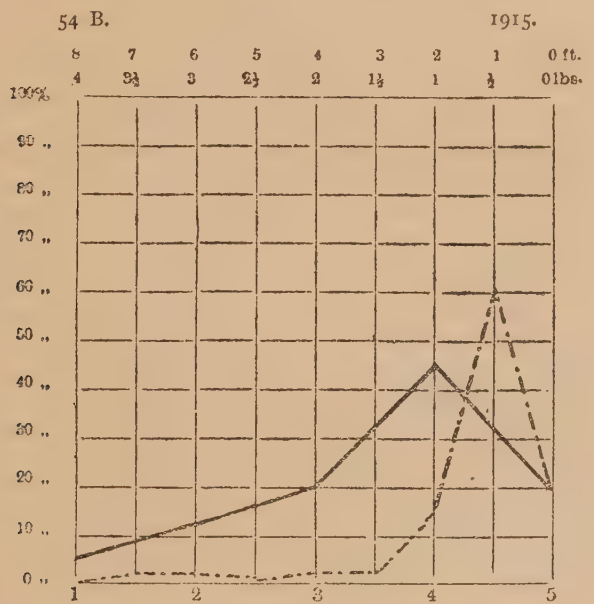

Fig. 4.

——— Cropping Curve.

..... Curve of actual weights of seedling crops.

to a gradual and increasing senility, but rather to an infection which, by reason of the anatomical severance of the embryo from the mother tissues, is unable to obtain access to the former.

I have some reason to believe that this immunity to infection on the part of the embryo may be occasionally overcome and that seedlings may be born degenerated, or more correctly, infected, before birth. Foex and Perret (9), state that this has been observed in Austria. Indeed in the tomato and some other species mosaic disease has been observed to be inherited.

The importance of the problem arising from the so-called degeneration of varieties to the future of the Potato Industry cannot be over-

estimated. In the opinion of the writer degeneration is but a symptom of a disease, and this disease is probably mosaic which for generations has been masquerading under the name of curl.

It is not proposed to enter at any length into the various steps which have been found to be efficacious in combating the scourge. The fact that varieties growing in certain localities, notably in Scotland, are relatively free from the disease, accounts for the common practice of obtaining seed from these parts. The long accepted and well established fact that immature seed tubers are perferable to mature ones may possibly be due to the circumstance that, being immature, they have escaped infection from the parent stock.

The old view that degeneration could only be controlled by the raising of new varieties has proved fallacious, for the great majority of the new types fail in their turn, when they come to be grown in the less favourable parts of the country for a few years in succession.

It would seem that the road to success is more likely to be found by breeding potatos with a view to immunity to mosaic and, if possible, leaf-roll also. That this is not impossible is borne out by the instances already mentioned. But the difficulty which presents itself to the breeder who is called on to produce a variety which, besides possessing all the required desirable characters in respect to growth, cropping and edibility, has yet to ensure its being immune to wart disease, to mosaic and kindred "degenerative" diseases, is great indeed. If the problem is difficult, and the labour great, yet is the benefit to be obtained overwhelming. In a word, immunity to mosaic is the key to immortality—for the potato. Such at least is the lesson to which the writer's experience would point. Already there are sufficient indications that by the industrious use of scientific methods based on the well grounded facts derived from the Mendelian analysis of the potato, the problem can and will be solved.

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THIRD SESSION.

THURSDAY, NOVEMBER 17TH—4 TO 6 P.M.

In the Chair: MR. C. G. A. NIX,
Treasurer of the Royal Horticultural Society and Chairman of the Fruit and Vegetable Committee.

THE NATURE OF IMMUNITY FROM WART DISEASE.

By V. H. BLACKMAN, Sc.D., F.R.S.

THE problem of the nature of immunity from wart disease has been thrown open to attack as the result of the investigations of Dr. K. M. Curtis, an account of which has recently been published (Phil. Trans. Roy. Soc., London, B.210, 409-478, 1921). In this work not only was the whole life-history of the causal organism, *Synchytrium endobioticum*, followed out for the first time, but the process of infection—which had completely escaped previous investigators—was fully elucidated. The zoospores or zygotes were found to come to rest on the surface of the young shoots, and then to bore their way through the walls of the epidermal cells. Once inside the host cells, they develop without injury to such cells, at least at first. A symbiotic relationship is thus for a time established, as in the case of club-root due to *Plasmodiophora Brassicæ* and of the cereal rusts.

It is very necessary for the economic control of wart disease that the nature of the differences between immune and susceptible varieties should be further analysed. Although investigations are in progress we have as yet no certain knowledge as to whether the disease resistance depends on anatomical characters or on more recondite physiological differences which lead to the death of the invading organisms after entry. It is quite likely that susceptibility and resistance may depend on a balance, or want of balance, between the physiological processes of the host cell on the one hand and the parasite on the other. That this balance, if it exists, may be shifted by certain conditions and the resistance broken down, would appear to be indicated by the observations of Schaffnit (Zeit. für Pflanzenkrankheiten, 30, 59, 1920), who claims that immunity from wart disease is not absolute, but that "degenerate" plants of immune varieties may lose their resistance and show a small percentage of infection.

SOME RESEARCH ASPECTS OF THE WART DISEASE PROBLEM.

By William B. Brierley.

(*Rothamsted Experimental Station, Harpenden.*)

In this paper I had intended to present results of investigations on the control of wart disease by the sterilisation of infected soil. The weather of this year has rendered vain all field experiments and at the eleventh hour it became necessary to change one's standpoint. It appeared that a useful purpose might be served if one sketched, suggestively, certain research aspects of the problem of the control of this disease as the matter stands to-day.

It would be easy to put into few words the main categories of our present knowledge. Thus we know that certain varieties of potato are immune from the disease whilst others are susceptible: we do not know wherein lies this difference, nor which type contains the determining factor. We possess detailed information regarding the structure and life-cycle of Synchytrium endobioticum as this fungus behaves under laboratory conditions; we do not know how far this truth holds for the complex reality of the field, whether indeed it be the only truth or whether there be not other and widely different stories to tell. We possess a mass of undigested data concerning the occurrence of wart disease, but we know little and understand less of the factors which determine this. Much information on the geographic distribution of wart disease has been gathered, but we are curiously ignorant of the critical dispersive factors, although shrewd guesses have been made. And so one could examine our categories, finding knowledge chiefly empirical and understanding slight. But, though interesting, this would serve an idle purpose and it is more to our gain to analyse our information and find wherein lies the difference between our knowledge of results and our understanding of their causes.

Immune Varieties.

Immune varieties are those which, under all soil and weather conditions, produce a clean crop in infected soil. If, then, immune varieties are stable, give good crops of high quality and show sufficient variety in type and times of ripening, why is not the wart disease problem regarded as solved? To speak quite plainly the immediate problem *is* solved—that growers shall cultivate only immune varieties. That matter is no longer one for the investigator, but for the administrator, educationist and publicist; and a well organised and skilful propaganda should soon enable one to state with practical truth "There

is no wart disease problem." But to accept this truth as a final solution, closing one's eyes to the fact that it is based on very limited experiments and depends upon many ill-understood conditions is mere shortsighted folly. The problem is an urgent one to-day and this is due to several causes, some objective, others psychological; the former may be mentioned.

Many susceptible varieties yield heavier crops than corresponding immune kinds ; and the former exceed the latter in number, affording wider scope for the selection of any desired type. Furthermore many well-known and popular varieties are susceptible ; and immune varieties are more restricted in their time of ripening, good "first earlies" being lacking. These deficiencies although a present inconvenience, are not a fundamental and permanent objection, for given time, good will and the adoption by potato raisers of modern selective and breeding methods, the desired qualities might be developed in immune varieties.

Immune varieties are criticised as wanting in that elusive element we call " quality "—as one well known grower, ripe in culinary experience, said to me, " Immunes are hard boilers." This may be fact or fancy and if the former it is very serious, for quality may well be bound up indissolubly with the character of susceptibility. It is, however, not a matter for prejudicial opinion and guesswork, but for the nicest quantitative estimation, and this problem is now being investigated by Mr. W. A. Roach in collaboration with the Mycological Department at Rothamsted.

Another factor to be considered, is the constancy of immune varieties. If there is any possibility of these breaking down in the very character which primarily justifies their existence, we shall be left in an infinitely worse predicament than before. The most hopeful solution will have failed us and the pathogen will have been distributed wherever potatos are grown. This question is not a simple issue, but is rooted in two aspects of a deeper problem, that of constancy of hereditary potentiality in the potato and in the fungus respectively. In considering these matters, we are confronted with the still more fundamental problems of the nature of immunity and susceptibility to the disease, and the nature and values of the exquisite physiological adjustments in the relation we term disease. One can only suggest these issues for they probe to the very springs of life itself.

Stability of the Potato.

In view of the great number of distinct varieties known, the potato is evidently rather unstable and as a result of bud sporting and so forth, genetic variations may occur in individual plants or tubers, immune plants giving rise to susceptible individuals or conversely. This process, however, is local and sporadic and can have no effect

on the primary issue of the general breaking down of the immune varieties. There is, however, the obstinate tradition believed by most growers and claiming source in long and repeated experience that potato stocks do degenerate. As I see the situation, and I put this as a considered opinion, no good evidence for senescence of stock due to long continued vegetative reproduction has been found. Also, I am aware of no evidence of gradual or rapid simultaneous change of any kind throughout an entire stock such as the belief in degeneration implies. The data of experience are usually frivolous and the hypothesis is at variance with modern genetic understanding. Stock changes may occur under specific conditions, as for example, deterioration of yield in northern seed grown in the south, but the explanation of these changes must be sought in other directions, such as infection by mosaic disease as suggested by Cotton, or by other systemic diseases, and not in degeneration, using this term in its genetic significance. There is no good case known of a breaking down of immune varieties in their distinctive quality; and, as all the evidence presents itself to me, there is no reason to expect that the immune varieties as distinctive types may under normal conditions over any period of time degenerate in any character.*

Stability of the Fungus.

The capacity of invading host plants may be due either (1) to a certain comparative degree of mechanical "strength" in the fungus protoplasm or (2) to enzyme production perhaps correlated with the presence or absence of activators and paralysers in the invaded tissues. Our essential problem of stability therefore is whether the fungus can be so altered by the selective action of external conditions, or directly by the impress of the factors of its environment, as to cause it to develop permanently "strength" such as will enable it to pierce mechanically the host tissues, or to develop such enzymes as might destroy the defensive mechanisms of the hosts. We cannot yet cultivate Synchytrium endobioticum *in vitro*, nor have our studies at Rothamsted given hope of immediate achievement. There is, therefore, no direct evidence regarding the genetic stability of this fungus, but there is a vast amount of analogic evidence, mostly very bad, from investigations on other micro-organisms. In short, the opinion generally held by students of these groups is that genetic changes constantly occur, and, most frequently, in just such characters as enzyme production and pathogenicity. I consider that this general opinion is uncritical and

* The only saving clause I would insert is in the not inconceivable event of certain characters being determined by a body only formed as a result of fertilisation. Long continued vegetative reproduction might exhaust this body with consequent degeneration in specific characters. There is, so far as I am aware, no case known of any character whose inheritance is conditioned in this way

obscures the finer issues and almost infinite complexities of the problem: it is an immediate and empirical solution. To my mind apparent changes in germinal constitution are, not only from the point of view of scientific method but also practically, better interpreted (1) in terms of modification, (2) of the selection of strains from a population, (3) of stages in a life-cycle of hitherto unrecognised complexity, or (4) as segregations from a germinally impure ancestor, than as true alteration in the potentialities of pure individuals. This divergence of views, which reflects a real difference in fact, has the most immediate and vital bearing on our problem. Synchytrium endobioticum has yet given no indication of the existence of physiologically differentiated races and *ipso facto* of a population out of which virulent strains might under certain conditions be selected. On the other hand, a process of sexual fusion occurs and I believe such phenomena to be the source of most true genetic changes in micro-organisms. If, however, the germ cells are identical as described by Curtis, and if Synchytrium endobioticum is a single physiological entity, and if the germ cells cannot mate with those of other Synchytria or allied organisms concerning which matter we know nothing, then there is no reason to anticipate that new strains of the fungus may arise possessing new qualities—possibly those of more extended pathogenicity. The above statement has been qualified to an almost meaningless residuum and this is very necessary, for our ignorance of genetic causality in micro-organisms is profound. As the evidence presents itself to me, I am compelled to read protoplasmic impurity underlying all change in hereditary potentiality and a primary factor in the causation of such impurity is sexual fusion. Wherever, therefore, sexual fusion occurs there is, to my mind, no certainty of germinal stability, although this process does not necessarily involve consequent genetic variation. One must, however, face the situation of the majority opinion, that pathogenic and other germinal qualities of micro-organisms may change rapidly or gradually in degree or kind apart from sexual or environmental causation. In such case, although the immune varieties of potatos themselves remain perfectly constant, they yet may break down in the particular character of immunity. However much, therefore, one may will to believe in the adoption of immune varieties as the final solution of the wart disease problem, the permanency of this solution is at the present time entirely an open matter with ultimate probabilities on the negative side. Until therefore this vital question of the genetic stability of fungi and bacteria is settled—and Dr. Henderson Smith and myself are investigating this extremely difficult problem at Rothamsted — there is no security of tenure for the immune varieties; true, they are in possession, but a writ may be served at any moment. If the fungus be unstable, there is no permanent solution of the wart disease problem save the total elimina-

tion of Synchytrium endobioticum from the soil—or the elimination of the potato.

In spite therefore of my earlier statement that I believe the immediate problem to be solved by the existence of immune varieties, it is obviously imperative that researches on methods of soil sterilisation such as the Mycological Department at Rothamsted is carrying out should be continued on a far more extensive scale than our present financial resources and laboratory facilities allow.

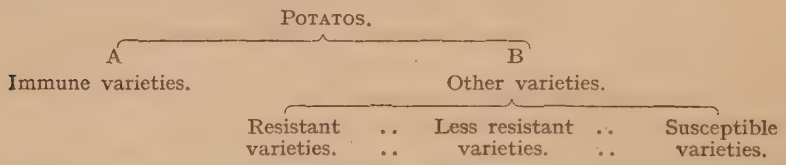
The Nature of Immunity to Wart Disease.

The condition we term disease is not static but the visible expression of an ever varying continuous interplay of physiological relationships. The diagnosis at any one moment is the picture of the *status quo* in a conflict between invasive and defensive organisms, this dual complex being moulded by environing forces such as temperature, food, light, humidity, etc. Both organisms are themselves the specific expressions of germinal potentialities interacting with external forces. The outward form and semblance of these expressions may therefore change with changing conditions, the qualities of host and parasite altering without any alteration in germinal factors. Thus a turgid plant may wilt under dry conditions or become etiolated in darkness, and a fungus may secrete certain enzymes and produce green spores, whilst on a different food medium it may give rise to colourless spores and other enzymes. In the fungus-host complex the changing qualities due to variations in environing conditions are always interacting, the values adjusting themselves to each other and, severally and unitedly, to external factors. Thus a turgid plant may be invulnerable to a parasite, whereas the same plant in a wilted condition may succumb. At a temperature of 25° C. a fungus may infect a healthy plant, whereas at a temperature five degrees higher it may fail completely to invade this same plant. During the present year, the abnormally high soil temperature,* a matter of a very few degrees, rendered Synchytrium endobioticum impotent to attack even the most susceptible varieties. I have instanced but two factors, desiccation and temperature, but under natural conditions innumerable forces are interacting; there is an infinite series of permutations and combinations, the more extreme being nullified by limiting factors. That is, a condition of disease is essentially the outcome of interacting values in a physiological complex, the complex itself and the values which compose it interacting continuously, severally and unitedly, with the ever-varying forces of the environment. All conditions of

*Probably not the dryness, for our experimental pots at Ormskirk (in which susceptible varieties grown in badly infected soil gave clean crops) were watered by Miss Whitehead, to whom our grateful thanks are rendered.

disease are therefore relative; that is, to our present issue, there is no absolute immunity from wart disease. This however is a theoretical dictum, and the practical truth is that there are varieties of potato which in none of the widely divergent conditions in which they have been grown have shown susceptibility to the disease. The explanation of this which presents itself to me is as follows.

Viewing comprehensively the data relative to wart disease, varieties of potato seem to fall into two sharply defined classes, the immune varieties and all the others. If we leave the immune varieties and survey "the others" two things may be noted: one, that under like conditions the several varieties differ in their susceptibility to Synchytrium endobioticum; and two, that under different conditions the same variety shows differential susceptibility to the disease. I have no exact figures myself for this, but results quoted by Snell and by Taylor lend much colour to the suggestion and the opinion has gradually formed in my mind quite independently as a result of much critical field observation of wart disease at home and abroad. It can of course only be proved by the most careful field experiments and one would like to see this aspect of the problem become a recognised feature of the Ormskirk trials. The relation is shown in the following diagram:—



The immune varieties are divided discontinuously from the others; the former are a homogeneous body, whereas the latter are heterogeneous, showing a continuous range from high degrees of resistance to complete susceptibility depending upon germinal potentialities and environing conditions. The problem of what constitutes immunity or susceptibility to the attacks of Synchytrium endobioticum is thus not a simple issue and the conditions to which attention has been drawn suggest interesting lines of thought of which two may be indicated. The immunity of the one class under all conditions that have been tried suggests that the determinant of the immune quality is stable outside the extreme tested limits of modifiability of both the immune variety and the fungus. From one point of view this indicates something quite specific of the nature of a definite chemical substance toxic or inhibitory to fungal growth present only in the immune varieties. It would seem too constant and stable a factor to be of a structural nature, for this would be subject to modification, or chemical of a mere accessory kind, such at tannin, mucilage, etc., for such are present in very variable proportions.

The suggestion is strong of the presence of some perfectly specific substance such as a particular alkaloid or glucoside which is an integral factor in the metabolic structure of the immune varieties.

On this view the different susceptibilities of the several varieties under like conditions might indicate a structural basis lying in differential thickness or tensile strength of the cuticle or turgidity of the cell, a purely mechanical thing. The different behaviour of the one variety under different conditions would indicate variations in this mechanical defence due to slightly altered functioning of the host under changed circumstances.

An alternative line of thought suggests that immunity may be due to the absence in certain varieties of a specific chemical substance essential to the economy of Synchytrium endobioticum. Potatos would then divide into immune and susceptible varieties according to whether this particular substance was absent or present in the plants. The immune varieties would constantly be immune either because they have lost the potentiality of forming the specific substance or never had it. The other varieties would show differential susceptibility because under like conditions the several varieties would produce different amounts of the specific substance, or any single variety under differing conditions would produce different amounts.

Another aspect of the problem of immunity or susceptibility to wart disease concerns the disease relations of parts within the individual. In immune varieties all portions of the plant are immune; In susceptible varieties the shoot system only is open to attack*; in Solanum nigrum, S. dulcamara and S. lycopersici, both shoot and root systems are susceptible. Comparative investigation may throw much light on the nature of immunity and susceptibility to wart disease, and physical-chemical and biochemical studies are being carried out by Mr. W. A. Roach in collaboration with the Physical and Mycological departments at Rothamsted.

Viewing comprehensively the question of immune varieties one must admit that they represent a certain and immediate solution to the problem as it exists to-day. At present it is the only solution available and, so far, it has shown no signs of being of a temporary nature. Nevertheless, it is very far indeed from safe or wise to accept it as the single final solution, for such can only be one which eliminates and not merely ignores the disease-causing organism.

Disease and External Factors.

The relation of " varying susceptibility " to wart disease has yet to be mentioned. I have indicated the nature of the fungus-host com-

* Records of root infection are probably Spongospora subterranea. In the experience of all recent observers, and I have spent many hours examining plants for this purpose, all potato root systems are immune from wart disease.

plex in the condition we term disease and alluded to the fact that this is a resultant state in which the interacting values are unstable varying with changes in external conditions. In this state the values are relative and those on one side may be increased by direct addition or by reduction in opposing forces. Thus Bewley has shown in the Lea Valley that tomato plants suffering from sleepy disease may be assisted by raising the temperature of the glasshouses, a few degrees being sufficient to retard or inhibit the fungus. Conversely it is a usual practice to give potash to plants suffering from certain diseases, this, not because of any influence it may exert on the fungus, but because of its direct additive effect on the plant. The adjustment of values in the disease relation is nowhere, I think, shown more strikingly than in the mangold crop on Barnfield, at Rothamsted.

The bearing of this on the problem of wart disease is immediate. The issues may be put thus. Can we, by cultural treatment, increase the resistance of susceptible varieties so that they may withstand the fungus and produce clean crops in infected land? Alternatively, can we, by soil treatment, retard the physiological activities of the fungus, decrease its protoplasmic pressure, or inhibit its secretion of certain enzymes so that it will be unable to attack susceptible varieties? In brief, can we artificially adjust the delicate physiological values in the fungus-host complex and weight the balance to favour the potato plant? In spite of previous work I still feel hopeful of positive results, for there are so many untried lines of investigation that the question is to my mind entirely open.

The modification or increasing of plant values is a simple experimental issue and need no further be discussed.

The second aspect of the problem presents several avenues of approach. The obvious one is a straight frontal attack in which by treatment of the soil with various physical "agents," such as temperature, desiccation, light, etc., or by the addition to the soil of various chemical substances, we seek directly to render the fungus innocuous. A second line of attack is to defeat the fungus, as it were, by trickery; but here we are impeded by our ignorance of the development and life-cycle of Synchytrium endobioticum under field conditions.

We know that the resting sporangia of the fungus exist in the soil and that when susceptible varieties are planted the crop is diseased, even if there has been an intervening period of ten or more years during which potatos have not been cultivated on the land. There are four primary hypotheses to explain this.

(*a*) The sporangia remain quiescent in an encysted condition, only germinating when stimulated by contact with potatos. On this assumption there is no inherent reason why, in the absence of potatos, the sporangia should not remain in a viable state for very long periods of years.

(*b*) The sporangia germinate in the absence of potatos and if a host be not available death ensues. The sporangial germinations would thus form a normal frequency curve and in the absence of susceptible varieties the fungus would die out in a strictly limited period of years.

(*c*) The fungus attacks species other than the potato and these alternative hosts enable it to tide over periods when potatos are unavailable. It is known to occur on Solanum nigrum, S. dulcamara and S. lycopersici, but search has failed to reveal it on common weeds of potato fields.

(*d*) The sporangia germinate in the absence of potatos and live saprophytically in the soil, re-encysting in due course.

The first hypothesis is improbable, for sporangia germinate in pure water; the second is the most probable, but it may be complicated by phenomena of the third and fourth. If not, and the complication is improbable in the practical issue, it suggests that, if some method could be found of eliminating the resting period of the sporangia, it might be possible to clear soil of Synchytrium endobioticum by inducing germination in the absence of host plants. With many fungi artificial induction of premature germination is easy and claims have been made for success with the wart disease organism. At Rothamsted, Miss Glynne is repeating these investigations, but so far has failed to substantiate them. Only in the experiment summarised below has there been a suggestion of positive results and this is being repeated and extended.

Treatment.	Actual Numbers.			Percentages.	
	Total.	Normal or vacuolated.	Empty.	Normal.	Empty.
Sporangia placed in water and examined after 20 days ..	2200	1983	217	90.1	9.9
Sporangia subjected to freezing temperatures and then placed in water at room temperature.	1200	967	233	80.6	19.4
Examined after 2½ months ..	1200	998	202	83.2	16.8
Sporangia placed in extract of whole tuber of Arran Chief, and examined after 20 days	1200	856	344	71.3	28.7
Sporangia placed in extract of whole tuber of Arran Chief and examined after 2½ months	1200	588	612	49.0	51.0

It is possible, therefore, to cause more than a quarter of the sporangia to germinate after a short period and over one half to germinate

in ten weeks. By modifying potato extract or discovering some other substance which might cause all the sporangia to germinate within a limited period, it might be possible to eliminate Synchytrium endobioticum from the land. If the fungus has resources other than the potato no solution of this kind is feasible.

Soil Sterilisation.

The only safe and final solution to the wart disease problem is the killing of the disease-causing organism ; that is, a solution which does not temporise or palliate but straightly removes the source of the trouble. The only obvious method by which this may be achieved is the drastic application of toxic physical or chemical agents. It is a simple matter so to treat the soil that the fungus is killed outright, but it is also essential that the method be financially economical and, perhaps of even greater importance, the treatment adopted must not alter or deteriorate the land for potato-growing purposes. In addition to the preservation of the delicate balance of the soil, the great difficulties of this problem centre in the extraordinarily resistant qualities of the resting sporangia of Synchytrium endobioticum.

At Rothamsted and Ormskirk we are conducting extensive soil sterilisation trials using chemicals and methods efficacious in the simpler problem of the treatment of glasshouse soils. The basis of our studies is to mix intimately with the soil certain volatile chemicals which have been tested for toxicity *in vitro* in the laboratory. The sporangia in the soil are killed and in a few days or weeks the chemical passes from the soil leaving it innocuous to plant growth.

I may conclude by noting aspects of the wart disease problem under investigation at Rothamsted. Quality differences of immune and susceptible varieties, the nature of immunity resistance and susceptibility to the disease ; germination and the development of the winter sporangia under laboratory and field conditions ; the manurial and cultural treatment of the potato plant in its relation to disease ; and the problem of soil sterilisation I have already mentioned. Of the greatest value would be a laboratory test of the viability of resting sporangia in treated soil and Miss Glynne has secured results which indicate that this problem is by no means insoluble. A second asset would be a laboratory method of testing the susceptibility or immunity of seed-potato tubers without the necessity of field trials and this possibility is being examined.

The problems of wart disease are some of the most difficult that we have to face and in most directions of research there is yet only an abundance of hypotheses. At Rothamsted we are still in a condition of travelling hopefully.

M. FOEX then took the chair and invited discussion on the two papers which had just been read.

PROF. POTTER thought that the incidence of diseases depends largely on environment, of which one of the most important factors is the degree of soil alkalinity or acidity. *It had been shown that in an alkaline soil club root did not occur, but the complete change from acid conditions to alkaline in the soil was very difficult to bring about. Greenhouse experiments had given him some suggestive results, for in one case, where warted tubers were planted in pots, in which carbonate of soda had been added to the soil (1 oz. to a 6-in. pot), the warted part had been sloughed off and the new tubers were wart-free. He hoped that perhaps there might be a working margin between the alkali tolerance of the potato and that of Synchytrium.

MR. BRYAN could not agree that wart resistance was likely to break down. All available evidence pointed to its permanence. Snowdrop and Schoolmaster had long been grown in wart-infected soils and were still immune to-day. Diagnosis of wart was not always easy. He mentioned a case of disease in Rector which superficially had all the appearance of wart disease, but which proved to be "corky scab," to which Rector and Tinwald Perfection were both very subject. In 1921 climatic conditions had prevented severe attack in the early part of the year. At Ormskirk, two lots of Sharpe's Express lifted on August 12th were free from wart, while three lots lifted in October were badly infected with wart in a fresh state, all having been grown on equally infected land and planted on the same day.

DR. BURNS asked whether the varieties, to which Dr. Blackman referred as having been reported in Germany to have taken wart disease in certain circumstances, were known to be immune.

MR. G. C. GOUGH said he felt far from certain that, where varieties were said by Schaffner to have broken down, the stocks were really pure. In his experience, immune varieties, no matter how degenerate, did not lose their immunity. He suspected that the material Schaffner had used was mixed with susceptible varieties as had been the case whenever similar cases have been reported in England. He thought there was hope of controlling the disease by altering the reaction of the soil.

MR. HALL said that charcoal had prevented the development of the disease in some experiments which he had carried out in infected soil.

MR. BUCHANAN asked how Dr. Brierley reconciled his view that degeneration does not occur with the view that the breaking down of immunity is possible.

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* See Potts, Report of the British Association, South Africa, 1905.

Dr. Pethybridge complimented Dr. Curtis on her researches, and regretted that her work had been interrupted, for there existed many great gaps in our knowledge of wart disease. He thought Dr. Brierley unduly pessimistic. For practical purposes we had immune varieties, and we had no evidence that immunity would break down. In some cases, it was true, plants appeared to lose their capacity for resistance, *e.g.*, in the case of Phytophthora, but three factors must always be considered: the nature of the host, the environment in its effect on host and parasite, and the nature of the parasite. We did not know upon what basis wart resistance rests—a very serious gap in our knowledge. It was possible that soil treatment might have an effect and it was certainly worth investigating. In the pots at the Experimental Station of the Royal Agricultural Society, lithium nitrate in certain doses was found to give immunity to wheat against Erysiphe (mildew). He had tried certain chemicals against wart disease, but with no success so far, but still perhaps there was a way of attack here.

Prof. Foex said the question of immunity was very complex and, in his experience with vines, was dependent to some extent upon climate. Under certain climatic conditions, resistance appeared to be lessened. He had, however, had no experience with wart disease.

Mr. Cuthbertson said he had a sound hope that resistance to wart disease would be maintained, as it had now continued in some varieties for many years. As a grower he was not afraid of degeneration. If the life of a variety was twenty years, that was long enough.

Dr. Brierley replied briefly. He said he was not pessimistic and did not think the change from immunity to susceptibility likely to occur, but there was always a danger and perhaps particularly a danger that the fungus itself might evolve new powers of infection, and they must be prepared to face this possible danger. The experiments suggested by Prof. Potter and Mr. Hall had been tried, but had not in other hands proved successful. Experiments with such things as lithium and borax were being tried, for it is just possible that such substances as these will alter the balance between plant and parasite in favour of one or the other.

SOME INFORMATION ON THE HEREDITY OF IMMUNITY FROM WART DISEASE.

R. N. Salaman, M.A., M.D., Barley, Herts,
and
J. W. Lesley, Plant Breeding Institute, Cambridge.

The heredity of immunity from wart disease presents a fascinating problem to the Mendelian, and at the present time it is probable that the solution of this problem would prove of great value to the breeder of immune varieties.

Biffen was the first to show that a character of this kind may be inherited in accordance with Mendel's law of segregation, and that resistance to yellow rust of wheat behaves as a recessive to susceptibility.* Since then the principle of segregation has been found applicable to other characters of this kind, including resistance to eelworm in barley, according to Nilsson Ehle.†

It is clear from the valuable experiments begun by the Harper Adams Agricultural College in 1909 and continued at Ormskirk by the Ministry of Agriculture and the N.I.A.B. that varieties of potato may be divided into two groups—those susceptible to wart disease and those immune. However favourable the external conditions may be for the parasite it cannot overcome the internal conditions which obtain in an immune variety.

It is highly probable that there are differences in the degree of susceptibility. For example, President is reported by Mr. H. Bryan to be far more susceptible than British Queen. On the other hand, it is clear that the power to resist the parasite is a *constant* character. Thus Sutton's Abundance was found to be immune in 1909 and has remained immune ever since.

The object of our experiments is to determine whether immunity is controlled by Mendelian factors and, if so, in what manner, and the paper we are reading to-day must be considered merely as a preliminary report. There is good reason to hope that our experiments and those of other breeders will ultimately afford a complete genetical analysis of this important character so that it may be possible to predict with certainty the proportion of immune seedlings which are to be expected from any given selfing or cross. The choice of parents may thus be facilitated.

The method of testing the reaction of the seedlings belonging to the experiment was to plant a number of tubers of each in the infected

* *Jour. Agric. Sci.*, Vol. I, No. 1, p. 40, 1905.
† *Hereditas*, Bd. I, Pt. 1, 1920.

soil of a plot at the Potato Testing Station, Ormskirk. No pains were spared in order to make the test as severe as possible. The plot was dressed with a layer several inches thick of heavily infected soil and also with a dressing of infected manure at the rate of 40 tons per acre. Although the early part of the season of 1921 was exceptionally unfavourable to the development of the disease, the August rain coupled with the special treatment of the soil and the late maturity of most of the plants combined to give a satisfactory result for late varieties, though early-ripening varieties, especially those lacking in vigour and in yield, gave results which are probably unreliable, many having escaped infection.

The seedlings were raised at Barley and Cambridge in 1920, and were grown on by tubers at Ormskirk. On the whole they made vigorous and often luxuriant growth and gave good yields. As a rule every seedling in a family was grown on and tested without any selection, the number of tubers of each averaging about 5 and ranging from 1 to 26. An association between immunity and small number of sets was found indicating the greater probability of small samples escaping infection. There is also good reason to think that feeble plants which give a poor yield tend not to show wart. We incline to the view that vigour and yield are quite as important as number of sets for field testing purposes. Obviously a high degree of precision was not to be expected. A laboratory method of testing single tubers or possibly even young seedlings would be the ideal one, and it is to be hoped that such a method may soon be perfected by pathologists.

The tubers were planted on April 4, 1921, and the plants observed on July 15 and on August 17. The first lifting was done on September 25 and the final one on October 25. In all some 440 different seedlings were submitted to the test.

In the selfings and crossings from which these seedlings were derived parchment bags and the ordinary precautions were used unless otherwise stated. The progeny of each berry was kept separate to serve as a check.

Families from two immunes selfed were grown. From Leinster Wonder selfed 18 different seedlings were tested and behaved as follows :—

Not warted	14
Warted	4

From Edzell Blue only self-set berries were available, but the results from separate berries were consistent. The test gave :—

Not warted	22
Warted	6

These immune varieties when selfed do not breed true, but each throws a proportion of susceptibles. Immunity here behaves as a

dominant. If we suppose that Leinster Wonder and Edzell Blue are both heterozygous or hybrid for a single immunity factor, the expectation on selfing such plants is that three-quarters of the offspring will contain this factor and will, therefore, be immune, while one-quarter will not contain the immunity factor and will be susceptible, in other words the ordinary 3 : 1 ratio. This seems to correspond fairly closely with the actual proportions found. Provisionally therefore we will assume that each of these varieties is heterozygous for a dominant factor which confers immunity. On this hypothesis it should be possible to find an immune which bred true for immunity.

From a cross between the two immune varieties Golden Wonder and Leinster Wonder 21 seedlings were tested and reacted thus :—

Not warted	14
Warted	7

This proves that two immune varieties crossed together may throw susceptible offspring, as indeed was to be expected from the selfed data just given. The present may again be a ratio of 3 immune to 1 susceptible such as would result from a cross between two heterozygous plants. The behaviour of its selfed seedlings has already shown that Leinster Wonder is heterozygous, and the figures here support this and suggest that Golden Wonder is also heterozygous for an immunity factor.

From another cross between two immune varieties, Kerr's Pink and Champion II, 79 plants were tested and classified as follows :—

Not warted	76
Warted	3

The average number of tubers planted of each seedling was $4\frac{1}{2}$, the plants were practically all vigorous, of late maturity. and mostly gave good yields, so that considerable reliance can be placed on these figures.

Again immunity behaves as a dominant, but in this case clearly more than one factor must be at work.

Let us suppose that two factors—X and Y—are present, either of which confers immunity, so that an X-containing or Y-containing plant is immune. If Kerr's Pink and Champion II are heterozygous for both X and Y, the expectation is 74 immune to 5 susceptible, which agrees well with the observed data. This cross, therefore, indicates that two separate factors exist each of which is sufficient to give immunity, and that Kerr's Pink and Champion II are each heterozygous or hybrid for both factors.

The next crosses to which we shall refer are between susceptibles and immunes. Two varieties which we raised for experimental

purposes in 1912 were tested at Ormskirk in 1920 and proved susceptible.

One of these (Kew 3×K23.17) with a complex pedigree containing S. Edinense and Congo crossed with Leinster Wonder gave a family which was almost uniformly vigorous at Ormskirk. They reacted as follows :—

Not warted	15
Warted	22

Susceptible × immune in this case seems to give about half susceptible offspring and half immune. From previous tests there is reason to believe that Leinster Wonder is heterozygous for one of the immunity factors. If the susceptible parent here is a double recessive with neither X nor Y, the expectation is half immune and half susceptible, or 18 immune to 18 susceptible against 22 immune to 15 susceptible actually found.

The second susceptible (Kew 2×ER'63 nat 78) was crossed with Shamrock. About half of the offspring were immune and half susceptible, viz. :—

Immune	17
Susceptible	21

a result similar to that of the preceding cross. Presumably then, the susceptible parent is again a double recessive and Shamrock is heterozygous for one of the immunity factors. We have no other evidence relating to these two susceptible varieties or to Shamrock, but the results do not conflict with the hypothesis.

The susceptible variety Edgecote Purple selfed gave rise to a rather uneven family, some plants being vigorous, but the majority feeble. They were noted as follows :—

Not warted	20
Warted	22

Some of the apparent immunes gave very poor yields, and are hence unreliable, but other were vigorous and yielded well; we are led, therefore, to assume that the proportion of warted is too low. From this latter result, immunity would appear to be a *recessive* and not a dominant as previous evidence has indicated. If, however, we assume that a factor B is present in Edgecote Purple which inhibits the immunity factor Y, so that a plant containing B and Y would be susceptible, then, if Edgecote Purple contains the inhibitor B in a heterozygous state and the latent immunity factor Y in a homozygous state, its formula would be BbYY and the expectation would be three-quarters, *i.e.*, 32 susceptibles against half, *i.e.*, 22 actually found, which is, of course, a serious discrepancy. More reliable data must be sought from this susceptible variety selfed.

A reciprocal cross between Edgecote Purple and Edzell Blue gave

two families in which the majority of plants were strong and gave good yields. The results were as follows :—

Edzell Blue × Edgecote Purple—

Not warted	40
Warted	23

Edgecote Purple × Edzell Blue

Not warted	17
Warted	11

These figures show no significant differences in the reciprocal cross indicating that the male and female sexual cells carry the same factors as far as these concern wart disease.

We have seen that the data from Edzell Blue selfed suggest that this variety is heterozygous for one immunity factor. If this immunity factor is Y, Edzell Blue would be Yy. Now if Edgecote Purple contains B, the inhibitor of the immunity factor Y, as previously suggested, and is heterozygous for B and homozygous for Y (BbYY), the present cross would be of the type BbYY × bbYy and should give half immunes and half susceptibles.

The actual results again show a considerable excess of immunes. It may be that the feebler lots counted as wart free may eventually prove to be susceptible, but this must await confirmation.

From a cross between Edzell Blue and a susceptible variety, Myatt's Ashleaf, 11 white-tubered seedlings were tested. All were vigorous and gave good crops with the following result :—

Not warted	1
Warted	10

The apparent dominance of susceptibility here is remarkable, as Edzell Blue is the immune parent, and again suggests that an inhibitor of immunity is at work introduced here by the susceptible parent—Myatt's Ashleaf. Edzell Blue being heterozygous for Y (Yy) Myatt's Ashleaf is probably heterozygous for B (Bb) or even homozygous (BB) if, as is possible, the single immune found is due to experimental error.

Two other immunes were crossed with Myatt's Ashleaf, viz., Snowdrop and Witch Hill, two varieties which are held to be identical in all but name. Unfortunately several of the offspring from these crosses were early, and so probably escaped infection, while others were feeble or consisted of small samples. The association between "poor crop" and "not warted" was pronounced.

Snowdrop × Myatt's Ashleaf gave :—

Not warted	16
Warted	7

Witch Hill × Myatt's Ashleaf gave :—

Not warted	27
Warted	26

These results contrast with that from Edzell Blue×Myatt's Ashleaf, which gave nearly all susceptibles, so that it is reasonable to suppose that Snowdrop and Witch Hill contain a different immunity factor from Edzell Blue. It must be the X factor to which Snowdrop and Witch Hill owe their immunity and they are heterozygous for this, Edzell Blue on the other hand contains the Y factor and Myatt's Ashleaf the inhibitor of " Y " immunity B.

Edzell Blue × Myatt's Ashleaf gives an excess of susceptibles because the B factor present in Myatt's Ashleaf inhibits the immunity factor Y contained in Edzell Blue. But Witch Hill (or Snowdrop) ×Myatt's Ashleaf yields about half immunes because the immunity factor X for which Witch Hill is heterozygous is not suppressed by the inhibitor B. This cross may be represented as Xx × BB = XB + xB.

It appears therefore that immunity is of two kinds, one depending on the factor Y as in Edzell Blue, the other on the factor X as in Witch Hill. X and Y are independent and in any immune one or both must be present. Susceptibility is also of two kinds, that merely due to the absence of both the immunity factors X and Y, and that due to an inhibitor of immunity B. A plant of the latter class may contain the immunity factor Y but not X.

It is superfluous to say that these experiments are only in an early stage and that this hypothesis is only put forward provisionally and has not yet been fully tested. The evidence certainly suggests that immunity and susceptibility to wart disease cannot be expressed completely by a single pair of factors. Both immunes and susceptibles seem to belong to several genotypes. Edzell Blue when crossed with Myatt's Ashleaf gave nearly all susceptibles, but when crossed with Edgecote Purple some 50 per cent. immunes. Evidently, therefore, the choice of the susceptible parent is of importance to the breeder of immune varieties. Again, Edzell Blue×Myatt's Ashleaf seems to give a smaller proportion of immunes than Snowdrop × Myatt's Ashleaf. The conclusion here is that some immunes are to be preferred to others as parents, and that for this purpose Edzell Blue is not a desirable immune. But the factorial composition of *both* parents has to be considered: in other words it is the combination which counts. A susceptible homozygous for the inhibitor B (BB) crossed with an immune homozygous for Y (YY) would give all susceptibles, and is therefore, a most undesirable combination, but the same susceptible crossed with an immune homozygous for X would give all immunes.

So far as it goes the evidence suggests that no advantage is to be expected from making a cross in one direction rather than in the other. In other words it is the factorial composition of the respective parents which is important, whilst the question of which acts as mother and which as father is immaterial. No correlation has been observed

between behaviour to wart disease and flower colour or tuber colour.

It so happens that we have not found a homozygous immune, but there is, of course, no *a priori* reason to believe that such will not be found in some or other variety or that it may not be isolated by appropriate experiment. It is of interest to note, however, that all the varieties we have tested are heterozygous.

In conclusion, the authors wish to express their thanks to Prof. R. H. Biffen for his advice, to Mr. H. Bryan of the N.I.A.B. for his valuable co-operation, and to Miss Hagger of Barley and Miss Whitehead of Ormskirk for their unfailing help.

Mr. Malthouse asked whether the selection of the white seedlings out of Edgell Blue for testing for immunity might not have given a different result from that obtained by taking the whole of the seedlings both coloured and white. At any rate, in some tests he had made the figures were very different from Mr. Lesley's.

Mr. Lesley said they had found no correlation between colours of tuber and immunity.

Dr. Burns said it was necessary to consider the second generation in all these experiments in breeding for we might hope to obtain from it much more information. He urged the importance of obtaining plants as parents which were homozygous for immunity. It was, however, evident that practical breeders need not fear to use susceptible varieties as parents, for out of them may come immune varieties.

Dr. Salaman emphasised some of the points dealt with in the paper and pointed out that he looked upon it only as a preliminary sketch. He laid stress on the results of the crosses with Kerr's Pink and Champion II. because these varieties had probably a double factor, while Golden Wonder and Leinster Wonder had a single factor for immunity.

The session closed with a vote of thanks to M. Foëx.

FOURTH SESSION.

FRIDAY, NOVEMBER 18TH—10.30 TO 1.30.

MR. W. R. DYKES, Secretary of the Royal Horticultural Society, in the Chair.

SOME RECENT WORK ON THE POTATO BLIGHT.

By GEORGE H. PETHYBRIDGE.

As is well known, the blight is a disease of the potato plant involving the destruction of the haulms and foliage and resulting in the decay of the tubers, which, unless concurrently destroyed by other micro-organisms—in particular by saprophytic bacteria—succumb to a characteristic form of dry-rot. The cause of the blight lies in the attacks of a parasitic fungus now known as *Phytophthora infestans* ; and the degree of attack is intensified by moderately warm and moist weather conditions.

The prefix " late " has, in recent years, been added to the name of this disease in America, where another disease affecting the foliage only, and designated the " early " blight, sometimes prevails. This is caused by an entirely different fungus, viz., *Alternaria solani*, and even if it occurs in the British Isles at all, this disease is of no economic importance here. The term late blight, however, is not an appropriate one even in America ; and it is desirable that its use should be discontinued, for outbreaks of potato blight by no means necessarily occur late in the season, but may, and indeed very often do, occur quite early. Thus, in 1920, blight was prevalent in Cornwall in April, and in each of the two previous years early in May ; while in the west of Ireland outbreaks frequently occur during the latter month. The earliness or lateness of the appearance of blight in any season depends partly on locality, but also on weather conditions and other factors.

The blight seems to have been first recognised in Europe and in North America in the early forties of last century, South America being its home and that of its host plant. At that time it was undoubtedly a new and hitherto unknown disease in the first-named countries and its appearance and rapid spread caused consternation and disaster, particularly in the years 1845 and 1846. From the economic point of view the potato blight is still the most serious disease which attacks

this crop, and the diminished yields and actual losses occasioned by it, though difficult to estimate accurately, are truly enormous.

How the disease managed to cross the Atlantic need not be discussed here, but reference may be made to Jensen's [8] * suggestion that it was probably connected with the replacement of sailing ships by vessels driven with steam. Other examples of plant diseases crossing the Atlantic are found in the two mildews of the vine and in the American gooseberry mildew, while examples of diseases crossing the ocean in the reverse direction are seen in the blister-rust of the white pine and in the wart disease of the potato, the last-named having reached the United States, probably from Germany, less than ten years ago.

What strikes the modern reader of the mass of literature published concerning the blight in the early days of its appearance is the large proportion of more or less wild speculation and conjecture indulged in as to its nature and cause, and the relatively limited amount of real investigation and research devoted to the elucidation of disease.

The early accounts of the blight cannot be dealt with in detail here, but attention may be directed to the important paper published in 1846 in the first volume of the Journal of the Horticultural Society of London (now the Royal Horticultural Society) by that well-known mycologist the Rev. M. J. Berkeley [1]. This is all the more necessary since this most valuable early contribution to a real understanding of the blight has, in the past, frequently been overlooked and, in some cases apparently, deliberately ignored.

The fungus which we now know to be the cause of the disease was observed at an early date, but the majority of writers then considered its appearance to be merely a result of the blight and not its cause. Berkeley, however, was one of that small band of scientific men who, from the start, had a clear and correct conception of the true state of affairs, and he distinctly stated that in his view " The decay is the consequence of the presence of the mould and not the mould of the decay." It is most unfortunate that Prunet [12], writing in 1902, erroneously includes Berkeley as a partisan of the non-parasitic rôle of the fungus, and further, that Jones, Giddings and Lutman [17] perpetuated this mistake in their admirable summary published in 1912.

The publication in 1861 of de Bary's account [2] of the potato blight marks an important step forward in our knowledge of this disease. This investigator described clearly and fully the way in which the parasitic fungus attacks the over-ground parts of the plant, forming on them copious supplies of spores. He followed the germination of these spores and showed how the parasite gained entry into

*Figures in square brackets refer to the literature at the end of this paper.

the tubers in the soil. He also showed that these spores were not sufficiently resistant to adverse conditions to permit of their remaining alive over the winter, but pointed out that the fungus was able to hibernate in the form of mycelium within the tissues of blighted tubers. He suggested then, and proved some years later, that such infected tubers might constitute a source from which an epidemic of blight could originate in the succeeding season.

Since other fungi, allied to that causing the potato blight, in addition to producing more or less ephemeral ordinary spores, were known to develop sexually-formed, thick-walled resting spores which are capable of carrying them over the winter, it was natural to suppose that such resting spores were also produced by *P. infestans*. Prolonged search for them in the tissues of potato plants and tubers destroyed by blight failed, however, to reveal their presence. Nevertheless the negative results obtained by de Bary in this connection did not satisfy other mycologists, and perhaps acted rather as an incentive to them to pursue more keenly the search for the elusive oospores. Matters may be said to have reached a climax in the years 1875 and 1876, when Worthington G. Smith [5, 6, 7] claimed to have discovered the resting spores, and to have observed the details of their development as well as of their germination.

Some few English mycologists accepted Smith's evidence as conclusive, but de Bary subjected the work to the closest scrutiny and criticism, with the the result that he was unable to accept Smith's conclusions. De Bary's paper, published by the Royal Agricultural Society of England in 1876 [3] should be consulted in this connection, as well as his later papers [4] in the Botanische Zeitung, 1881. As L. R. Jones *et al.* succinctly put the matter in 1912 [17], " the outcome has been the general acceptance by modern botanists of de Bary's verdict, 'not proved,' regarding Smith's work."

During the final quarter of last century there was a lull in the prosecution of studies relative to the supposed production of resting spores by the potato blight fungus, broken only in 1890 by a sporadic effort to demonstrate then on the part of a graduate student, Smorawski, in Breslau [9] ; an attempt, however, which to the initiated by no means carries conviction.

With the beginning of the twentieth century a new phase was entered upon. Hitherto all the investigations had been made on the fungus when growing parasitically on its specific host plant, the potato. But in the recent work, now to be dealt with, the fungus has been studied when growing alone and in pure culture as a saprophyte on dead substrata *in vitro*.

Matruchot and Molliard [10, 11] in France, in 1900 and 1903 respectively, were probably the first to succeed in getting the parasite to grow saprophytically in pure culture, while in America, Clinton [18]

and Jones [14], in 1906 and 1909 respectively, made considerable advances in this direction. Finally, in 1911, Clinton [20, 21] was able to announce definitely the discovery of the long sought for antheridia, oogonia and oospores of *P. infestans*.

In 1909 the Department of Agriculture in Ireland, stimulated by constant complaints from the west of that country concerning potato diseases which were not ameliorated by spraying—that is, diseases other than the blight—established a field laboratory at Clifden, Co. Galway, for the investigation of these diseases, but considerable attention was also devoted to blight.

Clinton's results were of such far-reaching significance that studies along similar lines were immediately undertaken at Clifden, with the result that his discoveries were corroborated and extended, while important additions to our knowledge of the peculiar method of development of the sexual organs in *P. infestans*, not understood by Clinton, were made by the present writer and his colleague, P. A Murphy, the results of which were published in 1913 [22].

It so happened that the work on *P. infestans* was being carried on simultaneously with observations on another fungus (subsequently described as *Phytophthora erythroseptica*) which causes the so-called ' pink rot " of the potato tuber as well as a wilt disease of the plant as a whole [23, 24]. In the case of this fungus the astonishing discovery was made that the female organ (*oogonium*) at an early stage, penetrates into the interior of the male organ (*antheridium*) at or near the base of the latter ; grows up through it and emerges at the summit, when it swells out rather rapidly forming a spherical portion in which subsequently an oosphere, which becomes finally a thick-walled oospore, develops.

Thus, the ripe sexual organs consist of a pear or balloon-shaped oogonium, having a thick-walled oospore in its upper, swollen portion situated above the antheridium, and having its conical or funnel-shaped base within and surrounded by the antheridium, the latter being thus amphigynous.*

Now, although the actual process of development of the sexual organs in *P. infestans* could not be followed directly under the microscope (as was possible in living material of *P. erythroseptica*), on account of the opaqueness of the only medium in which it was found possible to get them to grow, and on account of other difficul-

*A similar mode of development of the sexual organs has now been established as occurring in several other species of *Phytophthora* ; and the cytological details of the actual process of fertilisation have been worked out by Murphy [27] in the case of *P. erythroseptica*. Further, it has recently been found by H. A. Lafferty, that in *P. Fagi* and *P. Cactorum*, where the antheridia usually lie at the side of the oogonia and penetration of the latter by the former is lateral, the development of sexual organs with amphigynous antheridia occurs in a small percentage of cases. (*See* " Nature " CVII, April 14th, 1921, p. 204.)

ties, yet, since the final stages are the same in both cases, it is fair to conclude that the mode of development is also identical.

Since doubt has been cast in one quarter* as to whether *P. infestans* really does form its sexual organs in the manner described, the present opportunity is taken of presenting some further evidence on the point.

Owing to the nature of the medium in which they are developed it is very difficult to make satisfactory photographs of these objects, and the difficulty is much accentuated by the fact that the oogonium wall and that portion of the medium in contact with it become stained a deep brown colour, which cannot easily be got rid of by the ordinary clearing agents.

Nevertheless, one reasonably clear photograph showing an oospore contained in an oogonium the base of which is still surrounded by the amphigynous antheridium was reproduced in the paper [22], published by the writer and Murphy in 1913; and other examples of the same thing are to be seen in some of Clinton's photographs [21]. The observation of the hyphæ on which the sexual organs are borne is peculiarly difficult, because, during the process of extricating the organs as far as possible from the medium in which they are embedded (which is necessary in making satisfactory microscopical preparations), these hyphæ most frequently become detached.

The accompanying figures (a) to (l) (*See* Plate) are outline drawings of the sexual organs of *P. infestans* (magnified about 680 diameters) made with the help of a camera lucida by my colleague Mr. H. A. Lafferty, from original material. It is not necessary to describe them in detail, but it may be stated, that in (l) there is no antheridium, the spore in this case having been produced parthenogenetically. In each of the other eleven cases the antheridium, and the oogonium containing a thick-walled oospore are indicated. Where the lines are continuous, the organs in question were actually seen as delineated, but dotted lines indicate either that the particular portion was indistinct or was not present in the specimen when drawn. The most important feature in each case from the present point of view is, of course, the antheridium; and the figures show sufficiently clearly that this is present and is truly amphigynous, surrounding, as it does, the funnel-shaped base of the oogonium in each case.

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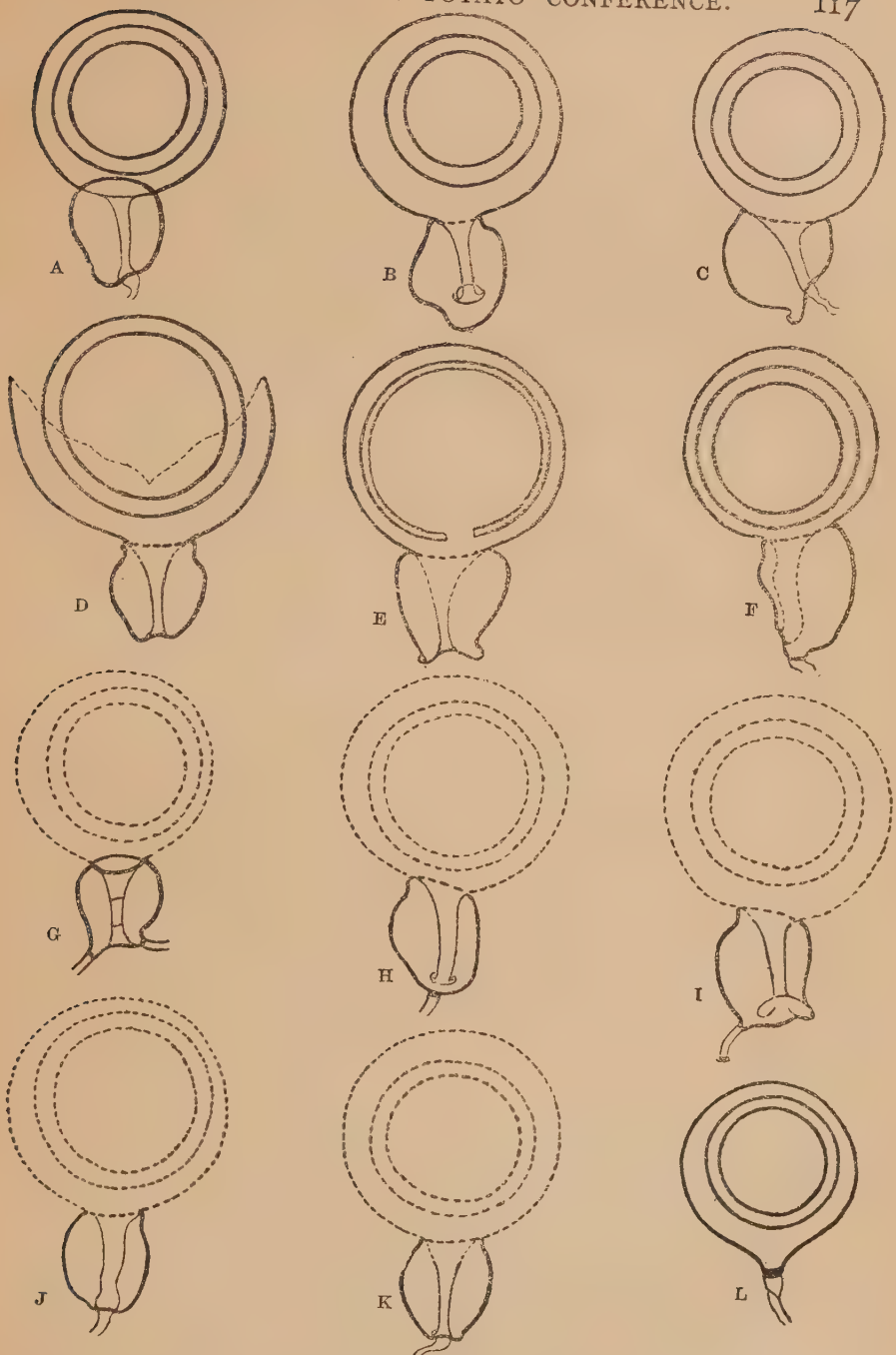
*J. Rosenbaum; in Journ. Agric. Research, viii, 1917, p. 264. This author states that in all the examinations he made of cultures of *P. infestans*, "only a few cases were found which might or might not be recognised as antheridia." The circumstance that he did not see undoubted antheridia, however, is not sufficient to prove that they do not exist, nor to controvert the fact that when they are produced, as they certainly sometimes are, they are of the amphigynous type described. Had his studies been less intermittent and more prolonged in character, doubtless he would have encountered unmistakable antheridia.



EXPLANATION OF PLATE.

A to K.—Sexual organs (antheridia and oogonia) of *Phytophthora infestans*. The upper large, comparatively thin-walled, spherical portion of the oogonium, in which a thick-walled oospore is indicated in each case, is situated on the top of the somewhat thicker-walled smaller and squarer antheridium, within which the funnel-shaped base of the oogonium is situated. In A, C, H, J and K a portion of the hypha from which the oogonium was derived is shown. In F, G and I the antheridial hypha is shown.

L.—An oogonium containing a parthenogenetically developed oospore. No antheridium is present.

(All much magnified).

It may be stated that. in pure cultures on Quaker oat agar, *P. infestans* often develops oospores in oogonia in the absence of antheridia, that is, parthenogenetically. Indeed, oogonia without antheridia (but containing spores) were much more commonly found than oogonia with antheridia. It is a possibility not to be overlooked therefore, that such parthenogenetic spores may occur in nature; but, if they do, it will only be possible to recognise them with certainty by the products of their germination.

The course of events as regards the behaviour of *P. infestans* in pure culture on Quaker oat agar is briefly as follows:—After growth has become established, and sub-cultures have been carried on at suitable intervals, no development of sexual organs occurs for some months, although the ordinary well-known asexual spores are borne abundantly. Parthenogenetically produced oospores of more or less normal appearance, and contained in either pear-shaped or spherical oogonia, then begin to appear in the sub-cultures in considerable numbers while, later on, associated with them, the combined sexual organs are to be found, but in far smaller numbers. The production of these bodies goes on for some time, perhaps for twelve months or so; but subsequently the formation of sexual organs in the sub-cultures begins to moderate and finally it ceases altogether. Meanwhile, however, the fungus continues to grow quite luxuriantly and still produces an abundance of ordinary spores; while its virulence as a parasite—as proved by inoculation experiments is in no way diminished. It would appear probable therefore, that the change in the mode of nutrition of the fungus when transferred from its host plant to an oat medium, or perhaps some chemical substance present in that medium, acts as a stimulus to the production of sexual organs. Nevertheless the effect or action of the stimulus wears off in course of time; and the fungus continues to bear asexually produced spores only.

The vexed question as to whether the potato blight-fungus does or does not form oospores may therefore now be regarded as definitely settled, the answer being in the affirmative. So far, however, the germination of these resting spores has not been observed and, up to the present, they have only been obtained when the fungus is growing in pure culture as a saprophyte. What part such bodies may play, if any, in the survival of the fungus and in causing outbreaks of blight has yet to be determined. It must first be ascertained whether these spores actually occur in nature; and work on this point is proceeding. From what has been done up to the present it can be stated that there are some indications that such may possibly be the case, but it would be premature and unwise to state more than this, owing to the insufficiency of the evidence as yet available.

The view that oospores are an absolutely necessary factor in the

perpetuation and incidence of the blight from year to year is of course untenable. It was shown by de Bary in his paper [3] published in 1876, that the disease may arise directly from the mycelium hibernating in a blighted tuber if the latter be planted. This fact was corroborated by Jensen in 1883, and has since been further confirmed by the present writer under greenhouse and garden conditions, and by Melhus in America [29] under field conditions; and there can be little doubt but that this is the source from which infection of the crop commonly occurs. Nevertheless cases, such as those recently recorded by Brooks [30], are met with from time to time, in which such a source would appear to be excluded: and an explanation of the phenomena observed would be more easy were it known that resting spores really did occur in nature*

During the last couple of years P. A. Murphy [28] has devoted renewed attention to the sources from which potato tubers become infected with blight. His experiments, some of which are not yet published, tend to show that the ordinary spores of the fungus are capable of retaining their vitality in the soil for a longer period than is commonly believed. The possibility is not to be excluded that ordinary spores produced on mycelium growing out into the surrounding soil from the surface of a blighted seed tuber or "set" may, in certain cases, cause infection of the plant derived from that tuber. Perhaps those rare cases in which new tubers become blighted in the absence of blight on the foliage may be explained in the same way.

In the foregoing paragraphs attention has been directed mainly to recent work concerning the parasitic fungus which causes the potato blight; in the space which remains some of the work which has been done in recent years in connection with measures for controlling the disease must be alluded to briefly.

In 1887 Jensen [8] published a paper, already alluded to more than once, in which he suggested certain means for combating the blight, and this paper deserves to be more widely known than appears to be the case. Experimental evidence was brought forward to show that infection of the tubers can be prevented to a large

*J. Eriksson's recent publication "Det primära Utbrottet av Bladmögel (Phythphthora infestans) på Potatisplantan," Stockholm, 1916, may perhaps be alluded to in passing; but it is exceedingly doubtful whether mycologists will be any more satisfied with this author's mycoplasm obsession as applied to the potato blight than as applied to cereal and other rusts. So far as the sexual organs of *P. infestans* are concerned, it is not a little remarkable that the structures which Eriksson describes as such, and which he found in blighted tissues, are totally different from the real antheridia and oogonia which are produced in pure cultures of this fungus. This fundamental difference appears to be totally ignored by Eriksson, and it is to be feared that his contribution to this subject is of no serious import.

extent by taking care that they are covered by a sufficiently deep layer of soil.*

Hence methods of protective moulding were devised which were more or less successful, but which have not come into general use, probably owing to the practical difficulties encountered in their adoption. Jensen also laid stress on the importance of choosing the right time for lifting the crop and of adopting proper methods for storing the tubers when dug. He also showed that the parasite in infected tubers could be killed by heat without seriously interfering with their vitality; and he devised a method for carrying out the necessary heat treatment. This, again, owing to practical difficulties, has never been extensively adopted, and indeed, unless it were universally employed, would be of little use.

Nowadays the means most extensively employed for preventing the blight is spraying the haulms with a liquid fungicide containing a freshly precipitated insoluble copper salt; and the two mixtures in common use are known as Bordeaux and Burgundy mixtures respectively. The former is prepared from copper sulphate and lime and the latter from copper sulphate and soda.

The first trials on potatos with a copper-lime mixture appear to have been carried out in 1886 by Jouet in France; and more precise experiments of a similar nature were carried out in the same country two years later by Prillieux, who, by means of spraying, obtained a 100% increase in crop and a reduction in yield of blighted tubers from 32% to 0%. The use of soda instead of lime was first suggested by Masson in 1887.

During the nineties of last century and, indeed, ever since then potato-spraying experiments have been carried on extensively in many countries, with the result that in many places spraying is now looked upon, and rightly so, as just as necessary an operation in growing potatos successfully as are proper cultivation and manuring. Ireland may, perhaps, claim to be regarded as having been something of a pioneer in this work, although the results of the earlier experiments made here remain hidden in the comparative obscurity of the pages of official blue-books.

The present Department of Agriculture on coming into existence in 1900 took over and continued the work of the Commissioners of National Education, the Irish Land Commission, etc., on potato spraying; and one result was that it was found possible to reduce the

*The erroneous idea that potato tubers generally become infected with the blight-fungus by the growth of its mycelium down the stalks, and out into the tubers through the rhizomes which bear them is one which, even now, appears to be tenaciously held in some quarters. Were this correct, then blighted tubers would always contract the disease in the field at their heel or stem ends first. Even a casual examination of blighted tubers in the early stages of attack, however, is sufficient to show that this is not the case.

amount of copper sulphate used in the earlier mixtures, until it was more or less stabilised at two per cent. More recent work carried on between 1911 and 1918 has shown that where the spraying is thoroughly done, and three applications are made during the season, a mixture containing only one per cent. of copper sulphate and the requisite quantity of soda is, on the average, just as efficacious as that containing two per cent., thus permitting a considerable saving in the cost of materials. This has recently been confirmed by experiments made in England by Salmon and Wormald [31].

Much other work has been done on potato-spraying, dealing with such matters as the method of application of the mixture, the best time to spray, the number of applications which are profitable, the value and efficacy of proprietary spraying materials, the use of sea-water instead of fresh-water in preparing the mixture, and so on. Space will not permit of the detailed results being given here, but they will be found in the issues of the Irish Department's Journal referred to in the list of literature given at the close of the present paper [26].

Attention has also been directed in recent years to the composition of copper-spraying mixtures from the chemical point of view, especially by Pickering [32], by Mond and Heberlein [35], and by certain French workers; while the question as to how these mixtures act on the fungus has to some extent been elucidated, if not finally settled, by the work of Pickering [33], and particularly that of Barker and Gimingham [34]. The evidence brought forward by the two latter tends to show that the insoluble copper compound is actually dissolved by the fungus itself, probably during the germination of the spore, rather than that the fungus is killed by a soluble copper compound liberated by atmospheric agencies from the insoluble one on the foliage, as suggested by Pickering.

Finally, something must be said regarding the question of blight-resistance in the potato plant. There is a fairly widespread belief which appears to be of a *post hoc sed non propter hoc* character, that the potato plant, in the early stages of its growth, is resistant to the attacks of the blight fungus, but becomes susceptible at or about the time of flowering. That this is not invariably so, however, was proved by the writer in 1909. Potatos were planted at Clifden, Co. Galway, at intervals of from seven to fourteen days over a period extending from March 11th to August 9th. The plants were of course not sprayed. When the blight made its appearance on July 11th, therefore, the plants in the plots were in various stages of growth. If the younger plants had been more resistant than the older, they would have been attacked less or not at all, and the latter would have been attacked first. This, however, was not the case. Some of the younger plants were attacked first, and soon the blight was distributed

indiscriminately over all the plots containing plants of varying ages; and ultimately all were equally destroyed.

There are undoubtedly certain varieties of potatos which are very strongly resistant to blight. As such may be mentioned "Champion II," "Shamrock," "Irish Chieftain" and "Northern Invincible," and there are probably others. In districts where conditions are favourable to blight epidemics, such varieties retain their green foliage in a healthy condition or but very little spotted with the blight (although unsprayed) right to the end of the season, and produce few or no blighted tubers; whilst neighbouring non-resistant varieties (sometimes in spite of spraying) may be cut down by blight and yield comparatively large quantities of blighted tubers.

It is unfortunate that these varieties are for the most part late ripeners, and although some of them produce fairly satisfactory yields, yet the cooking quality of their tubers generally leaves much to be desired. Further, it is regrettable that the power of resistance of a variety to blight appears to be a character which diminishes in the course of years, although culinary value may improve during the same period.

Thus, to take one example only, in 1879, a year when the attacks of blight in the British Isles were very heavy, the variety "Champion" stood out markedly as a blight resister. Nowadays, probably, it would be difficult to find a variety which was more susceptible to blight.

Even in the case of the resistant varieties mentioned above, or some of them, this loss of resisting power appears to be taking place. They have been grown for about ten years in succession at Clifden from the same stocks; and whereas in the early days it was difficult to find spots of blight on the foliage, and blighted tubers were very rare or absent altogether, in recent years spotting of the foliage has become more marked and blighted tubers are more common than was formerly the case. Nevertheless these varieties are still, on the whole, much more strongly resistant to blight than susceptible varieties such as "Up-to-Date," "British Queen," "King Edward," and many others.

It is not believed that the loss of resistance is due to infection with the so-called virus diseases such as Mosaic and Leaf Roll, nor does it seem probable that it can be due to an increase of virulence on the part of the parasitic fungus.

Wherein the power of resistance to blight lies is not definitely known, but from the small amount of experimental work which has been done on the matter up to the present it would appear that it is not of a mechanical nature, such as thickness of skin, impenetrability of the cell-walls and the like, but is due rather to the presence of some substance in the cells which inhibits the development of the

fungus mycelium within the tissues. The subject is one of extraordinary interest and demands further investigation.

Whether varieties of potatos exist which are absolutely immune from blight, comparable with those which have proved themselves to be strictly immune from Wart Disease, is not known. The search for them and the raising of them by breeding are problems for the future.

List of Books Quoted.

The list of papers given below makes no pretence of being exhaustive. Many of them, however, contain lists which will be found of great value to any one who desires to pursue the subject further :—

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[16] Jones, L. R. and Lutman, B. F.—Further Studies of Phytophthora infestans. Science N.S. XXXI. 1910. No. 802. P. 752.

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[21] Clinton, G. P.—Oospores of Potato Blight, *Phytophthora infestans*. Connect. Agric. Expt. Station Report. 1911. P. 753.

[22] Pethybridge, G. H. and Murphy, P. A.—On Pure Cultures of *Phytophthora infestans* de Bary, and the Development of Oospores. Sci. Proc. Roy. Dublin Soc. XIII. (N.S.) No. 36. 1913. P. 566.

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[34] BARKER, B. T. P., and GIMMINGHAM, C. T.—The fungicidal action of Bordeaux Mixtures. Journ. Agric. Science IV. 1911. P. 76.

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DR. SALAMAN asked whether the plants used as illustrations of resistance to Phytophthora were seedlings. His experience led him to be pessimistic concerning resistance to Phytophthora. In 1909 seedlings of *Solanum edinense* and a domestic variety were raised. Of these seedlings, in 1910, open to easy infection one-quarter proved immune to Phytophthora. In 1911 there was no Phytophthora; in 1912, when Phytophthora was prevalent, all the seedlings succumbed. He thought this was probably due to an alteration in the time of reaching maturity, for late maturing varieties often escape, *e.g.*, Shamrock, Champion II. and Northern Invincible.

M. DE VILMORIN asked whether there was any value to be attached to the chemical treatment of tubers as a means of warding off Phytophthora attack.

PROF. SALMON asked whether Dr. Pethybridge thought tomatos were likely to carry over the potato disease from season to season, and gave an instance of the attack on tomatos grown in greenhouses in spring. He was glad to know that Dr. Pethybridge advocated a 1 per cent. Burgundy mixture. He had often wondered whether the usual recommendation in Irish pamphlets to use 2 per cent. was based upon the wetter seasons there, but now concluded there was no other reason for it than common practice.

Mr. Wright suggested the desirability of investigating very thoroughly the source of outbreaks. It was known that at times the planting of diseased tubers resulted in nothing but healthy crops. Possibly resting spores may after all have something to do with the problem.

Mr. Baker asked how long a single spraying might be regarded as effective and what period should elapse between spraying.

Mr. F. J. Brooks said attempts at Penzance to ascertain the source of outbreaks suggested that resting bodies might be a means of carrying disease over from year to year.

Dr. Pethybridge said a small number of varieties were distinctly resistant and this was most marked in late maturing varieties, including Clifden Seedling, and the varieties Dr. Salaman had mentioned. He could not accept the common idea that infection could take place only when a plant had reached a certain age. In a series of plantings made over a big period in 1909, it was found that youth did not confer resistance to attack. Seedlings are not necessarily disease-proof, but resistance might be lost after many years. The varieties shown as resistant had maintained that character over 9 years. Unfortunately the resistant varieties were not of good quality. As a protection against blight soaking the tubers in copper-sulphate had not given good results, but heating for 2 hours at 40 deg. C. had killed the mycelium. This treatment was not, however, practicable, for it would need to be universal. He thought the tomato might be a source of infection, but usually infection appeared to come from elsewhere. Infection of crops usually came from slightly-blighted seed-tubers, although blighted sprouts were rare. The length of time between sprayings must depend upon the weather and the strength of the mixture, but in Ireland a single spraying might be taken as giving protection for a period of about three weeks.

Mr. Chittenden then took the Chair.

NEW WORK ON LEAF-CURL AND ALLIED DISEASES IN HOLLAND.

By H. M. Quanjer.

Introduction.

One of the first things necessary for workers in the big problem of leaf-curl and allied diseases is unanimity as to what is meant by the terms employed.

I have had the great privilege of visiting different potato-growing districts of America, France, Spain, England, and Scotland under the direction of the most competent experts; these visits showed me that the same types of diseases are prevalent in all these countries, and that they have the same importance. I will not speak here of diseases in which the curling or folding of potato foliage is a symptom of minor importance, as for instance the bacterial "streak" disease, in heavy cases of which a curling sometimes occurs, combined with the more characteristic phenomena of angular leaf spots, dark stripes on the stalks and leaf drop. Nor is it my intention to treat the more or less close folding up together of leaflets in the tops of wilting plants, as may be seen in attacks of Rhizoctonia, Verticillium, Sclerotinia and other soil parasites. Nor the downward curling, which, together with a dark bluish-green colour and afterwards a bronze glistening appearance, betrays a lack of potash in the soil.

This paper will be confined to the so-called "deterioration" or "hereditary" diseases—leaf-roll, mosaic and crinkle. These seem to infiltrate not only the entire plant quite regularly but even its progeny as long as asexual propagation is continued. I am studying five of these diseases, and there seem to exist even a greater number. The three more important ones are represented in the following scheme:—

Leaf-roll.—Leaflets erect, taking a yellowish or reddish tinge, and curling gently upward to a funnel-shape without much undulation.

Mosaic.—Borders of the faintly mosaicked leaflets undulating, increasingly so as the disease becomes more severe. The progeny of primarily diseased plants can take a "curly dwarf" form.

Crinkle.—Leaflets either faintly mosaicked or of a bronze colour caused by a number of fine dots; the borders and tips curled downwards. The leaflets rugged with deep depressions. Also showing a "curly dwarf" form and leaf drop in advanced stage.

Personally I am not inclined to retain the old name curl, though I know it is still used in England for what now is generally termed leaf-roll everywhere else. The old name leaf-curl has been used by growers in all the countries I visited for different types of these diseases. The same holds good for the name "curly-dwarf," since plants thus

designated sometimes belong to the mosaic, sometimes to the crinkle or the streak disease. The time is past for these diseases to be mixed up under indefinite names; we have to analyse and to use distinct names for distinct diseases.

Each of these troubles shows its characters more distinct the younger the plants, and consequently their leaves, are. The distinct character, especially in the case of mosaic, is lost sooner in a hot and dry climate than in higher latitude or altitude. Gradually a necrosis of the leaf tissue occurs which first gives the leaf a brownish appearance, but which at last shows itself as dead tissue at the tips and along the borders. This same necrotic appearance is seen in the case of potash hunger. When I visited England and Scotland, in the beginning of last August, it was so prevalent that the diagnosis of curl and mosaic diseases often was quite impossible. In some cases this brownish appearance was present when there were no distinct symptoms of curl, mosaic, crinkle, or potash hunger. Further experimental work is needed to find out the ætiology of this so-called "rust."

In Holland I have sometimes found necrotic patches on the somewhat rolled and yellowed leaflets of Paul Krüger (President) otherwise healthy on heavy soil in which respiration was defective. It is possible therefore that compacted soil may cause this "rusty" appearance.

Development of the Dutch Investigation.

Restricting myself now to the deterioration diseases of the curl type, the first thing which had to be done fourteen years ago, when I began their study, was to separate them. We did not know then of leaf-roll and mosaic; we only knew "curl." Varieties were said to deteriorate by curl, and gradually I learned to distinguish the leaf-roll type, and another type which reminded me of the mosaic disease of tobacco, first studied in Holland by Mayer and Beyerinck. In deteriorated varieties generally a combination of leaf-roll and mosaic was present. Afterwards Danish and American investigators also began to distinguish mosaic. In order to isolate leaf-roll or mosaic in pure culture, it is necessary to look for a plant showing the typical symptoms, to label it and to harvest it before it is ripe. It is most important that no symptom of any other disease must be present in the plant or its neighbourhood, since this by corrupting the purity of the disease will be of no use for experimental work. The longer the plant is left in the field the longer it is exposed to undesirable infection.

Everyone now can succeed in getting pure strains of leaf-roll or mosaic in this way, but as we were quite unacquainted fourteen years ago with the infectious character of these diseases, the fact was only learned by bitter disappointment.

Very important work in this line has been done and is still being done by Dr. Oortwyn Botjes in the North of Groningen (and

PLATE I.—FIG. 2.

PLATE I.—FIG. 5

PLATE I.—FIG. 4.

PLATE I.—FIG. 1.

PLATE I.—FIG. 2.—Top of plant attacked by Hypochnus Solani (var. Bravo). Note slightly folded foliage and premature flowering.

PLATE I.—FIG. 5.—Marginal leaf-roll (var. Duke of York). Note that only the borders of the leaflets are shortly upward curled. No change in colour takes place.

PLATE I.—FIG. 4.—Top of wilting plant as seen in the case of Verticillium and Sclerotinia-attack or injury of basal part of stem (var. Paul Krüger). Note the cigar-shape rolling different from the funnel-shape rolling in the case of Fig. 3.

PLATE I.—FIG. 1.—Top of healthy plant (var. Bravo).

published in his thesis in 1920) who, trying to eliminate leaf-roll by careful selection of healthy plants, drew my attention to the injurious influence diseased plants have on their healthy neighbours.

In Holland we have for some years divided the work, Dr. Oortwyn Botjes isolating healthy strains of different varieties for experimental purposes on his farm, consisting of 100 acres, and I isolating the different diseases on smaller experimental plots. We have separate plots for each of the different diseases, each plot having different varieties. One of these plots is used for leaf-roll, one for mosaic, one for crinkle, and so on. In some varieties mosaic very much resembles leaf-roll, and only by transmitting the disease in question on some standard variety, as Paul Krüger, or Bravo, I am able to identify it as mosaic. For this reason the study of leaf-roll cannot be separated from the study of the allied diseases, and it is only by a constant comparison of leaf-rolled, mosaicked, crinkled and healthy plants that I got an idea of what leaf-roll is.

At the present time I have got the real leaf-roll, a second form of leaf-roll, three different mosaic diseases, and crinkle in pure culture.

The question arises how to decide what true leaf-roll is.

Leaf-roll.

It is a dominant potato disease in the South of England, the Southern States of America, and the Continent of Europe, at least in certain varieties.

When a plant is newly infected, it does not show the rolling and upward position of the upper leaves until the middle of the summer. The upward bending of the stalk of leaves and leaflets is quite typical. In these upper leaves a reddish colour is sometimes very prominent, as I saw in a certain variety in Scotland, which was grown next to heavily-infected plants of another variety. The adjacent row contained 30 per cent. of newly-infected plants, the second row showed only very few infections, the third and fourth row were not visibly infected when I saw the plot.

Often newly-infected plants show their symptoms so faintly that one cannot be sure whether they have leaf-roll until the progeny has been examined. Sometimes newly-infected plants do not even show any primary symptoms at all.

Secondary leaf-roll plants (the progeny of the primary diseased ones) show the symptoms in the lower leaves at the beginning of the summer. The rolled leaflets stand upright and are funnel-shaped, rigid and brittle: a yellowish discoloration proceeds from the tips and the margins, followed in certain varieties by a reddish or violet tinge.

This description will not always be sufficient for diagnostic purposes.

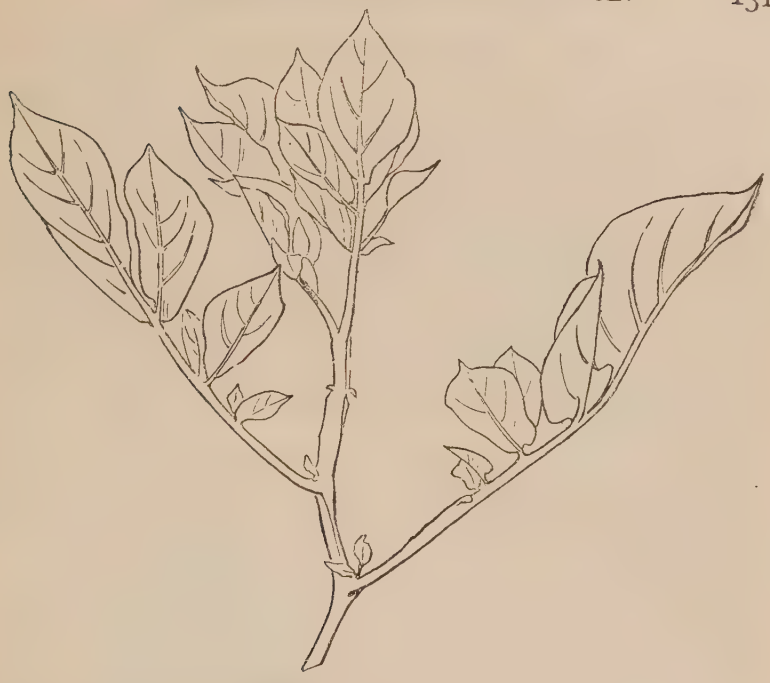

PLATE I.—FIG. 3.

PLATE II.—FIG. 7.

PLATE I.—FIG. 3.—Top of plant strongly attacked by primary leaf-roll (var. Paul Krüger = President). Note upright habit of leafstalks and leaflets and absence of undulation in borders. At basal part of borders a change in colour to yellow or red takes place.

PLATE II.—FIG. 7.—Gently upward undulation of leaf margins as occurs in the case of mosaic (var. Eigenheimer).

Seeking for a more accurate characteristic, I found the phenomenon of phloem-necrosis.

Leaf-roll always is characterised by phloem-necrosis in stalks and veins; the transport of starch from the leaves is prohibited. The secondary diseased plants remain small and produce only a few very small tubers (not a large number of rather small ones, as sometimes is the case of Rhizoctonia attack). Schultz and Folsom claim to have found net-necrosis and spindling sprout as characteristics of true leaf-roll, but I have not observed these as regular symptoms, though it may be that net-necrosis develops in leaf-roll infested tubers of some varieties, which, instead of being planted in the spring, are kept very long in cool storage. In this case spindling sprout is quite common.

True leaf-roll is transmitted by aphides (green fly) as was first proved by Dr. Oortwyn Botjes (1920), and afterwards by Schultz and Folsom (1921). The aphide experiments were undertaken during the last three years in insect-proof cages by Dr. Oortwyn Botjes for leaf-roll and by myself for mosaic. Selected and numbered tubers from healthy grown plants were cut into four pieces, one series of fourth parts was, during the latter part of the winter 1918–19, grown in a hot-house to control their state of health; another series of fourth parts of the tubers, which proved healthy, was afterwards grown for being infected by green fly fed on leaf-rolled plants; another series for the mosaic-infected green fly; and the last series for green fly fed on disease-free plants. The green-fly were transmitted with great care. All other insects were excluded from the experimental plants. We never came to a decision the same year whether lice transmission of the disease took place, since the symptoms of primary disease are not always to be trusted. But we always cultivated the progeny of each plant treated, and waited for the symptoms of secondary disease the following season. It was a slow method of experimenting, slower than that followed by our American colleagues, but the evidence obtained was conclusive. Every plant on which leaf-roll aphides were fed got leaf-roll progeny, every plant on which mosaic aphides were fed got mosaic progeny, and every plant on which healthy aphides were fed gave healthy progeny.

Leaf-roll spreads in the field from diseased plants to their healthy neighbours. The more the climate favours the development of aphides, the farther the infection goes. Tomatos and other solanaceous plants can carry leaf-roll without showing its symptoms as clearly as potatos. The experiments with these solanaceæ have been made in the same way as the aphides experiments, in insect proof green-houses. The different species were grafted with tops of leaf-roll plants, and afterwards the grafted tops were cut off and the remaining stocks were grafted back on healthy potatos. This is necessary,

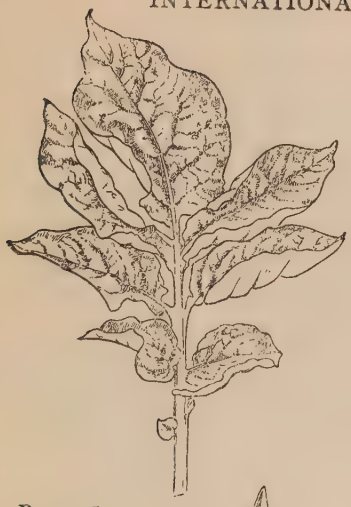

PLATE II.—FIG. 9.

PLATE II.—FIG. 6.

PLATE II.—FIG. 10.

PLATE II.—FIG. 8.

PLATE II.—FIG. 9.—Leaf with Duke of York mosaic (var. Bravo). Note that the area between the veins is lighter green than near the veins.

PLATE II.—FIG. 6.—Leaf with strong mosaic (seedling). Note soft transition of darker and lighter portions.

PLATE II.—FIG. 10.—Hereditary variegation as occurs in different varieties. Note the light band occupying a variable area along the margin, the normal green being limited to the centre, usually surrounding the midribs and separated locally from the whitish area by a lighter green.

PLATE II.—FIG. 8.—Leaf with Aucuba mosaic (var. President). The light patches are much more prominent.

because sometimes, as in the case of tomatos, leaf-roll can be carried without the plant showing it. Nishimura (1918) records the same experience for the mosaic disease.

The part played by other insects, as bugs, hoppers, leaf beetles, etc., is now being studied in the same way. These studies are not yet complete, but it can already be stated that none of these insects is so well adapted to transmit leaf-roll as is the green-fly, which, with its sucking mouth-parts, pierces the phloem portions of the vascular bundles, the seat of the internal disease-symptom.

Some of these insects, *i.e.*, hoppers (Empoasca sp.) have to be transmitted in large quantities to get the typical small white specks they cause. The great difficulty in these experiments is to exclude all green-fly.

Marginal leaf-roll.

Marginal leaf-roll, another form of leaf-roll, is much scarcer. Here the rolling is restricted to the borders, so that the leaflets do not become funnel-shaped.

This phenomenon is not accompanied by phloem-necrosis: the starch transport is but very little disturbed. Whether it is infectious or not is as yet undecided.

Mosaic.

True infectious mosaic is another dominant disease in the different countries I visited. The pale patches in the leaflet differ but little in shade from the darker portions of the leaf, and in hot dry summers they are quite indistinguishable. The faintly diseased plants show then only a somewhat crinkled and glistening appearance. The mottling only appears in the tops of late or second growth. This disease is carried by aphides, as is shown by Schultz and myself (published in Dr. Oortwyn Botjes' thesis in 1920). It can be transmitted by grafting to other solanaceous plants, *e.g.*, tomato and tobacco. It is not so easily transmitted as tobacco mosaic ; rubbing experiments, for instance, have no results. In the progeny of infected plants the curled or crinkled appearance develops and in some varieties it can take the form of curly dwarf.

Aucuba-Mosaic.

Another infectious mosaic occurring in different countries is characterised by more prominent but more localised yellowish patches.

It does not give a curled appearance to the leaves, and does relatively little harm. It can be communicated by grafting to other potatos, and to tomatos, as is the case with Lindemuth's infectious chlorosis of Malvaceæ. When Aucuba-mosaic potatos are grafted on Datura stramonium, Solanum dulcamara, Nicotiana tabacum, Atropa belladonna, and Hyoscyamus niger, these plants do not show its symptoms,

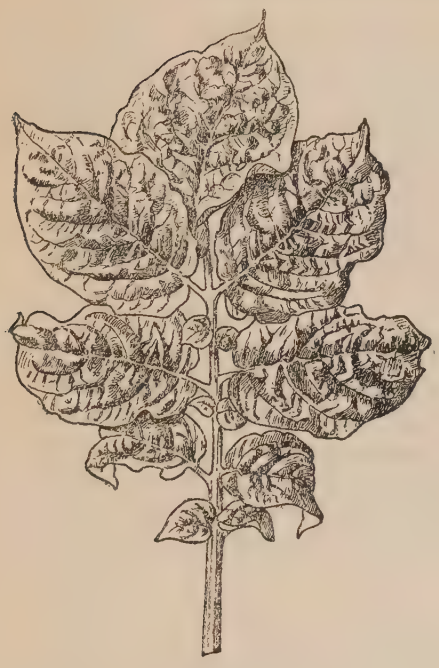

PLATE III.—FIG. 11A.

PLATE III.—FIG. 15.

PLATE III.—FIG. 11B.

PLATE III.—FIG. 12.

PLATE III.—FIGS. 11A & 11B.—Leaves with crinkle in variety Bravo. Note upward and downward depressions; the lower leaf (B) is yellowing and covered with fine dark patches; it drops prematurely.

PLATE III.—FIG. 15.—Potash hunger. Gentle downward curling of margins without depressions.

PLATE III.—FIG. 12.—Leaf with crinkle in variety Paul Krüger. Note downward bending of margins and tips of leaflets.

but they readily transmit the disease back to the potato. Grafted on tomato, it is well recognisable and distinct from the common tomato-mosaic. In order to distinguish it from the first described mosaic, and on account of its resemblance to the variegation of Aucuba japonica, I call it Aucuba-mosaic. It is not to be confounded with the marginal variegation which often is observed in potatos, tobacco, and other plants, and which is not contagious, but is inheritable and comparable to the periclinal-chimæræ of German authors (Winkler, Baur).

Duke of York Mosaic.

A third infectious mosaic is characterised by pale patches, chiefly between the veins; patches of the leaf tissues directly in contact with the veins remaining green. The margins of the leaflets curl a little bit upwards. I provisionally call it Duke of York Mosaic, having observed it for the first time in this British variety, which has been introduced into Holland, but afterwards I found it also in some Dutch varieties.

Crinkle.

Is an infectious disease, overlooked in England, but present and very injurious in nearly all the places I visited. It resembles somewhat mosaic, but it is more rugged, with marked corrugations, and the margin and tips of the leaflets are curled downwards. In other varieties a bronze tinge, caused by fine dark spots, prevails. The leaflets are very brittle; they yellow prematurely and the lower leaves may drop off easily when touched. In earlier years I have confounded it sometimes with mosaic, but, after a correspondence with Murphy two years ago, when he was still in Canada, I was quite convinced that I had better give it a special name and I have adopted his term "crinkle." I observed it especially in trial plots with American varieties introduced by a Scottish breeder, and in the old variety Cowhorn, which I introduced myself from America. It is sometimes difficult to decide whether diseases of this kind are imported from other countries with the "seed," or if the imported varieties are more susceptible than the home-bred and become seriously affected in a new country.

Crinkle can be very readily transmitted from one potato variety to another by grafting. Different solanaceæ: Tomato, Hyoscyamus niger, Datura stramonium, and Atropa belladonna, infected by grafting, show its typical symptoms, so that no doubt different weeds will be able to carry the disease. We have green-fly experiments with crinkle in progress, and their results must wait for the 1922 progeny, but the experience of a number of years has shown that crinkle is transmitted to neighbour-plants exactly as are leaf-roll and mosaic.

General Remarks on these Diseases.

In order to complete the description of the above described diseases, it must be stated that, as a rule, none of them show any marked symptoms in the xylem portions of the vascular bundles, either of the stems, or of the tubers. In the advanced stage of the three chief diseases, the plant, whose growth is largely reduced, is not able to exhaust the seed tuber.

Only in the case of leaf-roll, phloem-necrosis (necrosis of the sieve strands) and starch accumulation in the stalks and leaves occurs.

Some authors as Spieckermann (Germ.), Jordi (Sw.), confirm the correlation between leaf-roll and phloem-necrosis, others as Schander, Tiesenhausen, Esmarch (Germ.) and Artschwager (Am.) doubt its existence. Since I found this correlation in 1908, I have confirmed it up till now, and have no doubt as to its existence. The only thing I doubt is whether my critics know leaf-roll well enough to distinguish it from other phenomena. I myself often have difficulty in identifying it in varieties which are not familiar to me, and as regards the primary symptoms I sometimes have even difficulty in identifying them in well-known varieties.

In the case of crinkle, necrosis is often found in the parenchyma, near the conducting tissue of the phloem.

With regard to the infection of the soil, it is a fact that plants grown on plots where a potato crop was raised in previous years, some distance from potato fields, sometimes get the faint primary symptoms of one of these diseases. It is not safe to conclude from this experience that the infection winters in the soil, since the possibility exists of aphides having transmitted the infection. When such experiments are made under insect-proof gauze, and on soil which does not contain tubers left from the last crop, their results are negative.

The existence of a variety of related infectious diseases described above is somewhat astonishing for anyone who has not seen them; and for this reason I shall be glad to show to anyone these different types of diseases and even others in my experimental plots in Holland. All will then realise that there can be no question of external influences, physiological deterioration, or enzymatic disturbance being the cause. We have never succeeded in finding any causal organisms, but such a variety of symptoms, in my opinion, can only be explained by the hypothesis that there are a number of micro-organisms causing them. We have to take into account that diseases related to these occur in a number of plants. In tobacco in the Dutch East Indies, two or three different diseases of the mosaic type and two diseases of the curl or crinkle type are described. Sereh and mosaic in sugar cane, spike in santal, phloem-necrosis in coffee, mulberry dwarf disease mosaic in beets, in hops, different types of mosaic and crinkle in arachis, soya, and French beans, mosaic in broad beans, mosaic in cucumbers,

in lettuce, peach-yellows, peach rosette, carnation yellows, spinach blight, infectious chlorosis of Malvaceæ, Ligustrum, Fraxinus, Cytisus, ptelea of Cephalanthus occidentalis in Missouri, etc., some of which have been transmitted by juice filtered through Berkefield-filters, are further examples of related diseases. One can hardly deny the existence of a whole world of ultra-microscopic organisms, causing them. We have to leave the question of "enzymatic disease" or "virus" till later; we must first undertake very accurate ultra-microscopic research of both the plant and the transmitting insects. Why should this not lead us to discoveries comparable to that of the microscopic and ultra-microscopic insect-transmitted protozoa, which cause a variety of diseases in men and animals?

The work of Franca in Lisbon on the protozoon, Leptomonas Davidi, living in the latex vessels of different Euphorbeæ in tropical Asia, Africa, America, and South Europe, is very suggestive in this respect. The protozoon is transmitted by the bug Stenocephalus agilis, in which it passes a part of its life cycle, forming first rather large individuals, and later on, after isogamic conjugation, a great number of very small forms, 1 μ broad, and 4, 5 to 7 μ long, which accumulate in the saliva glands.

It will, therefore, be necessary not only to study pure cultures of these virus diseases in the potato plants, but also to study the transmitting insects, some of which must be exclusively fed on healthy potato plants and others on plants in which each of the described diseases is present in pure form.

Since, after many unsuccessful efforts, some pathogenic protozoa have at last been cultivated in artificial media, containing fresh albuminoid substances, this method ought to be followed also for the so-called virus diseases. The connection of the leaf-roll disease to the sieve tubes gives some hope that a proper choice of albuminoid substances may lead to success.

Prevention of these Diseases.

How seriously these diseases reduce the yield is now well known. Not only is the size of the tubers of diseased plants reduced, but also their number; the necessity of prevention is very urgent. What has been reached in this direction in Holland may be instructive for England.

First we have to give attention to the varietal susceptibility. Every potato grower will have noted differences in susceptibility between the different varieties. Further it is known that amongst the plants raised from true seed some must be rejected on account of leaf-roll and mosaic; in the second and third year of their existence other seedlings are discarded, so that only a small percentage of the seedlings give healthy promising varieties. This gives rise to the question:

PLATE III.—FIG. 13.

PLATE III.—FIG. 14.

PLATE III.—FIG. 13.—Leaf with crinkle in variety, "Jersey Nonsuch." Note great number of very fine dark patches, which gives to the leaf a bronze tinge.

PLATE III.—FIG. 14.—Grafting experiments of "Jersey Nonsuch" on Paul Krüger. Graft is attached between second and third lead from below. Top leaflets of Paul Krüger begin to get a faint crinkle, ower leaves get the bronze colour and drop at base of petiole. This leaf-drop is typical for crinkle.

" Has the infection been transmitted to the seedling by true seed or has the young seedling been infected ? " The only way of answering this question is to grow each seedling under insect-free conditions. Where this has been carried out, either by my colleague, Prof. Mayer Gmelin, in Wageningen, or by myself, we found that relatively few and sometimes no disease at all was present in the seedlings. Where it occurred there was doubt as to the reliability of the cages used. Nevertheless this question of transmission through the embryo has not yet been conclusively decided. It is known that the mosaic diseases of tobacco, mangolds, sugar beets and cucumber cannot be transmitted by the grain ; but Doolittle and Gilbert (1919) believe that such a transmission exists in the mosaic disease of wild cucumber, and the same way of transmission is observed by Reddick and Stewart (1919) in the case of the bean mosaic.

The practical importance of resistance is minimised by the fact that some varieties, which, in spite of the chances of infection, have left the grower as promising novelties, may subsequently prove to be very susceptible. It seems that the agents causing these troubles adapt themselves very quickly to new varieties. This may be the reason why, as a rule, all varieties after some decades have been discarded and why the practical man believes that deterioration of potatos is the consequence of their asexual propagation. It would appear to be not due to ordinary degeneration, but to their increasing susceptibility to disease and especially the type of diseases treated here.

I found that leaf-roll, mosaic and crinkle prevail in wild South-American varieties and species, which I got through the courtesy of American and French colleagues ; the same holds true for cultivated varieties which I got from American, English, French and German growers.

The potato plant has already been so much crossed that I doubt whether further efforts in combining the most heterogenous parent types can give new and better results. Instead of always producing something new, we should endeavour to keep the old local well-adapted varieties in good condition.

It must be kept in mind that the conceptions we have of susceptibility to different forms of disease, only have in the past been suggested to us chiefly by very rough observations on the variety plots. In order to try resistance in a more exact way (comparable to the wart-resistance trials at Ormskirk), we should plant healthy seed of each variety between two rows of plants infected by the pure forms of disease ; the progeny of each plant should be watched, and the percentage showing secondary symptoms noted. Seedlings of these varieties could be tested by the same method to see whether the resistance and susceptibility are really hereditary.

PLATE IV.—FIG. 17.

PLATE IV.—FIG. 16.

PLATE IV.—FIG. 18

PLATE IV.—FIG. 16.—Primary streak in variety Paul Krüger. Note black angular spots in upper leaves and the brown stripe running down the stem and leaves. Dropping of leaves. The brown colour is restricted to the cortex and does not affect the xylem-portions of the vascular bundles as has been described by APPEL and KREITZ (1907) for "Bakterienringkrankheit."

PLATE IV.—FIG. 17.—Secondary streak. Note downward curling of leaflets, black angular spots, stripes on stalks and dwarfing.

PLATE IV.—FIG. 18.—Frost necrosis in variety Duke of York.

These old varieties as well as the new ones annually produced in Great Britain, can be kept in a good state of health by selection. Selection in the case of potatos has not the same meaning as it has in the case of sexual propagated plants. It is not pollen of undesired types, but infection by insects which has to be excluded. The fact that the selection of healthy plants will not give any success on fields where curl is prevalent, is an old observation in Holland. The very best fields have to be sought if selection is to be successful. We are fortunate in Holland in having had a co-operative method of field-inspection of potatos since 1903, this being organised by our provincial Agricultural Societies, the inspectors not being State officials, but leading men of local reputation. In order to get a high price for the seed produced, the growers are only too ready to have their fields inspected by these representatives of their own society, whom they confide in. The condition of the field is estimated in simple figures, running from 1 to 10, only the fields indicated by 8, 9 or 10 are approved and recommended for seed by the society. It is due to the instigation given by this system of field inspection that roguing for disease has been in existence in Holland for twenty years and perhaps longer. Wart disease is one of the most serious troubles in England, and you have in your country an entirely different system of field-inspection, the intention being of discarding wart-susceptible varieties. In Holland, we, of course, rogue fields for extraneous varieties, but our chief attention in roguing is given to leaf-roll and related diseases.

But gradually, as research proceeded, we have been able to teach the practical man a better method, viz., the selection of the best individuals. The products of each individual plant are preserved separately and planted the following year in a row. The different rows are separated by rows of other plants, 5 yards broad, as mangold beets, common or broad beans, in order to prevent mutual infection. Each family, as we call the product of a row, is afterwards multiplied separately. Here again a lot of study is necessary. We found, for instance, in ordinary years Myzoides persicæ was the common potato green fly, but last summer the black aphis of the beets and beans (Aphis rumicis) was also found feeding on the potato plant in great number. It may, therefore, be necessary to exclude beans and beets in the future. The part played by weeds and cultivated plants, and of the insects feeding on them, as disease-carriers, will also have to have more attention paid to it than hitherto.

We have found that some regions of Holland are more suitable for the cultivation of healthy seed than others. In general, the heavy soils in the neighbourhood of the sea, in the provinces of Friesland and Holland, give better seed than the sand and peat soils of the east and south. In Great Britain, we see that potato-seed is better

PLATE V.—FIG. 19.

Healthy and diseased Red Star. It is difficult to see whether this form of what in America is called "curly dwarf" belongs to leaf-roll, mosaic or crinkle. This disease in Red Star has been transmitted by grafting on the variety Paul Krüger and proved to be mosaic. In the case of "curly dwarf" caused by crinkle of streak leaf-drop occurs at the base of the stalk.

PLATE VI.—FIG. 20.

Crinkle in the var. Bravo, showing typical depressions in the leaflets. In the secondary form the plant takes the "curly dwarf" type.

[*To face p.* 143.

the greater the latitude and the altitude are. One is inclined to believe that a hot and dry climate favours the deterioration. Experiments on this problem have been made in Holland. We planted potatos from one of the best approved fields in Friesland partly in the heavy soils in that same province, and in the province of Holland, and partly on the peat and sand soils in the east, where potatos are said to deteriorate. The experiment was undertaken with great care, each tuber being numbered at four places of its contour, and cut into four pieces. Complete series of fourth parts were sent to each locality, and planted in each locality in the same succession. The majority of the potatos were healthy, but a few plants affected with leaf-roll or mosaic were included.

On account of the above described system of planting, the diseased plants had the same position in the plot in each locality. The products of each plant were harvested and preserved separately in numbered bags, and planted the following year. In this way we discovered that in the sea-clay the diseased plants infect only their nearest neighbours, but that on the peat and sand soil the infection is carried over a much greater distance. We found also that the infection is carried further the more sheltered the situation of the plot, and it was also observed that in sheltered places and in the sandy and peaty soils more green fly occur on the potato than on the sea-clay where the wind is nearly constantly blowing.

But the problem is not solved by these observations, since green fly though less numerous, are also present in these last regions. We have a question here analogous to the malaria problem. The parasite causing this human disease is well known, as well as the midges transmitting it. Schwellengrebel (1920) showed that the same species of anopheles may occur in two places; yet malaria prevails in one and is absent in the other.

The difference in latitude and altitude between the South of England and the seed-producing potato districts of Scotland is much greater than between the different parts of Holland. I should like very much to repeat my experiments in co-operation with some of your potato experts, sending one series of fourth parts of potatos to Scotland, one to England, and planting the other two series in two different localities in Holland. We will divide the products of each separately harvested plant, in order to compare the progeny of each of them in England, Scotland and Holland. No doubt we shall have a sufficient number of healthy plants to see the direct influence of the climate, and also enough diseased plants to compare the distance of spreading in the different types of the climates and soils concerned. It is my hope that the experiment I just outlined may lead to closer and continued relations between the British and the Dutch investigators on the many problems connected with potato diseases.

Be this influence of the locality as it may, I believe that under any conditions selection will lead to a great improvement.

I have seen this summer wonderful results of selection of the Dutch variety "Red Star" on the isle of Tessel, which, by its extreme dryness, reminded me very much of the South of England. The state of health of the potato crop of most of the farmers of this isle was bad, but a young farmer who had been my assistant in his years of apprenticeship had undertaken selection of the variety "Red Star" on a big scale for four years. Whereas nearly everywhere else on the isle the fields affected by mosaic and leaf-roll dried up nearly completely in August, the fields of healthy "Red Star" of Mr. Dyt withstood the drought so well that they were green till October, and from everywhere in the neighbourhood he now gets demands for seed.

I should not like to close this address without expressing my wish that not only by import of seed from Scotland, but also by a good organised selection, the potato crop in the South of England can be improved. Success, however, comes not by wishing, but by hard work bravely done.

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SOME RECENT WORK ON LEAF-ROLL AND MOSAIC.

By PAUL A. MURPHY.

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Occurrence of Leaf-roll and Mosaic in Ireland.

DISEASES of the potato of the type of which leaf-roll and mosaic are the best examples have become the subject of general attention during the last ten or fifteen years. Their distribution is world-wide since they are carried in the potato tuber wherever it goes. The subsequent development which they attain depends on the extent to which local conditions are favourable or the reverse for the potato crop.

A partial survey carried out in 1920 showed that the leaf-roll occurred in Ireland and that both it and mosaic were somewhat more common than had been supposed, particularly on certain varieties. Circumstances prevented an accurate comparison, but the diseases were found wherever susceptible varieties were grown and there did not appear to be a marked difference in this respect between the North and other parts of the country, with the possible exception of the Dublin area. Taken on the whole, the crop was found remarkably healthy, but sufficient of the diseases (particularly the mild form of mosaic) was found to warrant investigation. In very rare cases more than 50 per cent. of leaf-roll was found in British Queen, Up-to-Date and Arran Victory, and occasionally from 80 to 100 per cent. of mosaic in Burnhouse Beauty, Irish Queen, and Irish Chieftain, amongst other varieties.

As the result of the inspection of about 200 lots of potatos it was concluded that the varieties on the following lists showed evidence of susceptibility or resistance :—

Showing Susceptibility to leaf-roll.	*Showing resistance to leaf-roll.*
Abundance.	Great Scot.
British Queen.	Shamrock.
Arran Victory.	Champion.
Up-to-Date.	Irish Chieftain.
Kerr's Pink.	Arran Rose.
Arran Comrade.	Arran Chief.
Majestic.	Tinwald Perfection.
Lochar.	Golden Wonder.

Showing susceptibility to mosaic.	*Showing resistance to mosaic.*
Burnhouse Beauty.	Great Scot.
Golden Wonder.	Up-to-Date.
Langworthy.	Arran Victory.
Irish Chieftain.	Arran Comrade.
Arran Chief.	Kerr's Pink.
Shamrock.	Arran Rose.
Tinwald Perfection.	Abundance.
Dargill Early.	British Queen.
Leinster Wonder.	

These lists are incomplete because many important varieties are excluded and the data regarding those included is so scanty in some cases that revision will probably be needed. The most remarkable feature about the varieties showing some resistance is that, with the possible exception of Champion and Arran Rose (which "rusts" badly), only Great Scot withstands both leaf-roll and mosaic. We now know that it can be infected with the former disease.

Field Experiments in Ireland.

More accurate information about varietal susceptibility to leaf-roll and mosaic is now being sought by interplanting the healthiest available seed of more than forty of the common varieties with diseased seed, thus ensuring uniform exposure to infection. It is probable that the finding or production of varieties strongly resistant to leaf-roll, mosaic and similar diseases will ultimately have to be relied on as the best means of control. Present indications that a variety with such all-round resistance, not to mention other necessary qualities, is in existence, are not very hopeful, with the possible exception of Great Scot. This being so, the attempt is also being made to rid partially-infected

plots of susceptible and somewhat resistant varieties of both leaf-roll and mosaic by means of roguing. Even when the roguing was done early in the season the results do not look promising, although the abnormal character of last season must be taken into account. A definite judgment cannot be given until 1922.

This work proceeds on the assumption that, as has been found to be the case, principally in Holland, the United States and Canada, we have to deal here with infectious diseases. Various infection experiments are being repeated, including the *role* played by insects and the distance from a diseased plant that there is danger of the infection being carried. That leaf-roll, at least, is capable of transmission between neighbouring plants is indicated by the accompanying photographs, which represent plants of the variety President, raised by Mr. A. D. Cotton at Kew in 1920 and exposed to leaf-roll infection in the field in one case and grown in comparative isolation in the other. Seed of these two lots was grown in Ireland in 1921 and that which had been exposed to infection produced only leaf-roll plants; while that grown in isolation produced plants which were initially all healthy. Later on, some of the latter contracted the disease from their neighbours and showed symptoms of primary infection.

Effect of Leaf-roll on Starch Translocation.

A considerable amount of work was done on the inner changes wrought by leaf-roll in the plant, particularly in regard to starch formation in the leaves and its translocation. It appears from these experiments that the lower leaves of secondarily diseased leaf-roll plants regularly contain an abundance of starch in the morning hours, while the corresponding leaves of healthy plants contain little or no starch. Of 21 such varieties examined, 19 showed a marked starch accumulation in the lower leaves, while in two it was less pronounced (Abundance) or irregular (Arran Victory). A faulty diagnosis may not be out of the question in either case.

Eight varieties were examined showing various transition stages between primary and secondary leaf-roll. So far as the work has gone it appears that starch accumulation in the lower leaves of these plants cannot always be relied on. On the other hand, it seems likely that the presence of starch in the morning in the upper leaves is an indication of primary leaf-roll infection.

These tests were generally carried out on leaflets cut from the middle or back portion of leaves on the westerly side of the plant from 10 to 11 o'clock in the morning. In the case of lower leaves, at least, this hour appears to be early enough, irrespective of the weather. Corresponding healthy leaves were always used for comparison. The leaflets were first boiled in water for a few minutes and then allowed to become decolourised in methylated spirit, which occurs

in a day or so. They were then transferred to a 1 per cent. solution of iodine in potassium iodide and left there 10 minutes or longer. The starch, if present, shows up at once, but the contrast between diseased and healthy leaves becomes more pronounced if the leaves are allowed to wash for two or three hours in water. With a little experience it is found that decolourising in alcohol is not necessary in ordinary cases, as the contrast between leaf-roll and healthy leaves, after boiling and treatment with iodine, shows up clearly by transmitted light.

The experiment works as well if the leaves are cut off in the evening and left standing in water in a dark room over night. Under these conditions the starch is retained by the diseased leaf as long as it remains alive, which may be for two weeks, but it generally passes out of the healthy leaf in one night. It appears from a single successful experiment that the starch test can be used for the diagnosis of plants sent through the post for examination. More work is needed to establish if starch holding in the leaves is constant under all conditions and with all varieties. If it should turn out to be so, it will prove a simple diagnostic symptom and may provide a new point of attack in the study of leaf-roll.

Effect of Climate on Mosaic.

Field experiments on mosaic were rendered nugatory so far as the greater part of 1921 was concerned by the very dry and hot weather which had the effect of suppressing the symptoms partially or almost entirely. It was already known from observation and experiment in Canada (as well as in the United States) that this might happen in certain warm and dry localities or seasons. Emphasis was there laid on the temperature, but the appearance of some mosaic for the first time in plants presumed infected from the beginning following the first good rain towards the end of July would indicate that moisture may also be concerned.

It was clearly shown in some of the Canadian experiments* referred to, that though the symptoms were suppressed in the case of diseased plants in certain places, with the result that their yield was hardly inferior that of neighbouring healthy plants, yet the disease was still present and transmissible. It reappeared in the diseased seed in the subsequent year under conditions more favourable to the disease in at least as intensified a form as before its suppression. Furthermore, mosaic appeared in the products of healthy plants which had been grown beside the diseased plants during the period when all appearance of the disease was suppressed. In other words, the infection can be conveyed from potatos in which the disease is latent and practically

* MURPHY: "Investigation of Potato Diseases." Dom. of Canada, Depart. of Agric. Bull, 44, 2nd Ser. 1921.

innocuous, to neighbouring healthy potatos. There may be some further information on this point from the current year's experiments. The disease, however, was not by any means fully suppressed in 1921, although as compared with 1920 it was strikingly less evident. Furthermore, the experiment is complicated by the fact that, again on account of the character of the season, the seed which was exposed to infection could not be examined satisfactorily for initial freedom from mosaic, but individual tuber controls, which were not near mosaic plants, are provided.

The interesting fact that the potato can act as a carrier of its own mosaic disease under certain conditions substantiates the work of Allard and Nishimura † among others. These investigators worked with tobacco mosaic and found that certain plants showed no pathological symptoms after infection, but were still able to transmit the disease. This suppression is held to be due to a measure of immunity in the plants in question. It is suggested that the explanation in the case of potatos grown under certain hot and dry conditions in Canada is similar, the temperature approaching the optimum (27° C.) for the growth of the potato and exceeding that for the development of the hypothetical mosaic organism. The latter may be concluded from the fact that the disease is most flourishing under cooler conditions. Due to this interplay of circumstances, the potato under the conditions mentioned becomes endowed with an increased degree of resistance.

Probable Nature of the Cause of Mosaic Diseases.

It is not necessary to labour the point that this and other reactions of mosaic point to the fact that the cause of the disease must be a living parasite, even though it has not yet been seen and may be ultra microscopic. The same conclusion follows even more clearly from the investigations of Allard on tobacco mosaic, and particularly from the fact that the "virus" in this case is filterable—that is, that through a filter of sufficient fineness infected sap passes, but leaves the infective principle behind. The parasitic origin of mosaic is also suggested by the inter-relations of the disease as it occurs in different members of the Solanaceæ, such as tobacco, tomato and potato. The three diseases in question are more or less transferable from one plant to the other and the organisms which cause them are at least very closely related. The differences which occur are comparable to the specialisation in parasitism found in other organisms which cause disease in plants. Even in the case of tobacco it appears from the work of Allard that there are two distinct mosaic diseases and this author has suggested that the common European mosaic of this crop may be distinct from the corresponding American disease.

† NISHIMURA: "A Carrier of the Mosaic Disease." Bull. Torrey Bot. Club. V. i. 45. 1918.

Bearing in mind, therefore, the possibility of there being more than one mosaic of the potato, there may be discussed the bearing of investigations in other countries on the question of the ultimate fate of mosaic-diseased plants in the British Isles. The question is—Do potato plants of the type so common in allotments, gardens and even fields in portions of the South of England owe their puckered rusty appearance and unproductive quality to mosaic in the extreme form ?

If the comparatively fine-looking plants which show the mild spotting of mosaic under more favourable conditions give rise to the rusty dwarfs of the South the matter is a serious one for all potato-growers.

Nature of " Rust."

In a very hasty search which I was able to make through portions of England in 1920, it was found that poor potatos were characterised by the presence of leaf-roll and mosaic in Lancashire and generally in Lincolnshire. In the latter place, however, particularly in allotments, the well-known " rust " began to put in appearance. In Middlesex and other districts around London the " rust " type of degeneration predominated over everything else. It was extremely common in native seed, but not in imported. As noted at that time, " rust " was found to include many types of diseased plants. These were listed as follows :—

1. Serious spotting and colouring of the leaves, the plants being extremely dwarfed, due to leaf-roll. Marked in President.

2. Browning or bronzing of the leaves similar to wind injury, This appears to be attributable to lack of some manurial element in the soil, possibly potash. Imported seed seems to suffer less from this trouble also than native—probably because of its being more vigorous it is able to fend better for itself on a partly impoverished soil.

3. Sharply-defined, black angular spots on the leaves without any trace of a bacterial or other parasite. Resembles a leaf-spot of unknown cause known in America as " physiological leaf-spot."

4. Somewhat similar spotting of the leaves, but with the discolouration running down the veins and into the leaf-stalk, and having the appearance of being due to bacteria. Indistinguishable from streak (American), and showing similarity to a phase of the German bacterial ring disease of Appel and to the disease described by the writer in Canada as leaf-drop.

5. More or less dwarfed plants with much corrugated, yellowish, downward-curled leaves which are not mottled like mosaic, but on which yellow areas and diffuse darkish spots develop in later stages, when the lower leaves drop off. Some of these plants appear to be identical with the trouble which was originally described as crinkle in Canada.

Two "President" plants grown at Glasnevin in 1921 from "seed" raised by Mr. Cotton in an isolated plot at Kew in 1920, the plants being then healthy.

A "President" plant grown at Glasnevin in 1921 (in same drill as above with same treatment and photographed at same time to same magnification) from same lot of "seed" as above, raised by Mr. Cotton at Kew in 1920 in a plot adjoining leaf-roll plants, the "President" plants being then originally healthy.

[*To face p.* 150.

Relation of Crinkle to Mosaic and "Rust."

The order of destructiveness of these diseases seemed to be leaf-roll, bronzing (apparently malnutrition) and crinkle Typical mosaic was negligible. The question is, then, are the crinkle plants an end-product of mosaic? On the Canadian evidence it was concluded that they were not. This evidence was based mainly on the fact that mosaic had never given crinkle, or crinkle returned to mosaic under good conditions. Furthermore, under dry-hot conditions in Central Canada, and also in the South of England, the ordinary spotting symptoms of mosaic may be suppressed and (in Canada at least) the plants may grow and yield so well as to be indistinguishable from healthy plants, but this does not occur in such seasons (or ever, so far as is known) with crinkle.

Perhaps the most striking evidence that crinkle is a separate disease is found in the behaviour of potatos at the Central Experimental Farm, Ottawa, Canada, during the last thirty years or so, where the first crinkle material was found.‡ For this whole period the crop has been under the same charge. For the first 15 years the potatos did more than well. There was no change of seed and yet the average yield at the end of the period was higher than at the beginning. Following a disastrous dry year in 1906, the situation was completely altered, for since then the seed has to be imported every year to secure a full crop and after that it is practically useless, the yield being in the neighbourhood of one-quarter of the normal.

The usual explanation given in such cases is based on climatic, seasonal, nutritional, or other physiological irregularities. In this case the disastrous drought of 1906 (with one or two subsequent dry years) is held responsible. Such an explanation, however, has largely lost its completeness in view of the proved infectious nature of the diseases responsible for the deterioration of potatos. In the particular crop under discussion these diseases were present to an overwhelming extent. It is obviously more likely that diseases which are capable of being transmitted from plant to plant and from year to year should be the cause of the present poor crops than that the effect of one or more bad seasons should still be felt not only by potatos which experienced them, but by those which were introduced since.

The particular point of interest in the deterioration of these potatos is that two of the diseases which make up the "rust" complex seem to be principally responsible—namely, crinkle and leaf-crop. Leaf-roll and mosaic are also present. In certain varieties at Ottawa crinkle is the main or sole cause of deterioration. If these plants represent merely the last stage of mosaic, it is hard to understand why mosaic did not assume the extreme form sooner, for this disease is

‡ MURPHY: *loc. cit.*

obviously long established in America. On the other hand, there was a considerable importation of European potatos to this farm in 1909, the year in which the deterioration set in. It is more likely that this seed brought with it diseases distinct from those previously present, being probably crinkle and leaf-drop. At the same time the influence of a new environment on foreign varieties must be taken into account. It is on such potatos that crinkle (but not leaf-drop) is commonest.

It is not maintained that the systematic position of plants of the crinkle type is settled, but more evidence is needed before their relationship to mosaic can be accepted. It should also be stated that it is possible that the type of severe mosaic with a dwarf habit which is known to occur may form a portion of the "rust" complex. Such plants, if they occur to any extent, would probably return to the more vigorous spot form of mosaic with favourable treatment.

Practical Control Measures.

As to the control of leaf-roll and mosaic, very little positive information is available. Roguing carried out early, persistently and thoroughly should prove useful, particularly if an isolated (but not shaded) seed-plot is maintained. Local experiments are needed on this point. This step, however, is merely a palliative and with many of our present varieties may not even be successful. A more lasting benefit would probably be secured by an attempt to produce new varieties with all-round resistant qualities.

The definite information available may be summed up as to its principal part in a sentence—namely, that the qualities of the seed potato which have the greatest influence on the productiveness of the coming plant cannot be judged at present by the appearance of the tuber. It is the appearance of the plant which produced the tuber which counts most. Since in most cases the seed-grower and the seed-user live far apart and since the user himself cannot look over the crop as a rule, some system of inspection for seed-borne diseases would seem to be necessary. Such systems have been evolved, and are being worked in Canada and many other countries. In Holland a system of inspection which has obvious advantages is carried out by the growers themselves, no doubt under supervision. Every country has its own particular problems, but perhaps a system to suit us could be grafted on some existing organisation.

THE SITUATION WITH REGARD TO LEAF-CURL AND MOSAIC IN BRITAIN.

By A. D. COTTON, Mycologist to the Ministry of Agriculture.

INTRODUCTION.

DURING the past few years the attention of plant pathologists in all parts of the world has been increasingly turned to the newly-recognised group of plant maladies known as virus diseases. Since the discovery by Dutch and American workers that several of the highly contagious "*mosaics*" are occasioned by a filterable virus which appears to have the properties of a living organism (ultra-microscopic), and that the diseases are transmitted from plant to plant in the field by certain specific insects, the parallel with certain animal diseases has been obvious; and to-day the complete elucidation of the virus disease problem forms one of the most fascinating subjects for research in phytopathology.

As far as Britain is concerned, by far the most important diseases of this group are potato leaf-curl and potato mosaic. Both of these very seriously reduce the yield and are inheritable in the sense that they are carried from season to season by means of the tubers. Several other virus diseases are known in England, *e.g.*, the mosaics of tomato, cucumber, beans, mangel, and tobacco; but none compares in economic importance with those of the potato.

The general position with regard to potato leaf-curl and potato mosaic is now fairly clear. As to leaf-curl (or leaf-roll, as it is termed on the Continent and in America), in spite of a vast amount of research, various theories as to fungus parasites and physiological derangements held sway till 1913, when Dr. H. M. Quanjer, of Wageningen, showed conclusively that the disease, though not caused by a fungus, was, nevertheless, infectious. After years of patient research Quanjer produced this evidence. He described at the same time the early phases of attack and subsequent development in the variety "Paul Kruger" (=President), and postulated his well-known theory of phloemnecrosis. His fellow-worker, Dr. Ortwyn Botjes, subsequently proved by careful experiments with insect-proof cages that the infective principle or "virus" (the nature of which is still unknown) was transmitted from plant to plant by means of certain species of aphides and showed that the stylets of the aphis penetrated the tissues of the veins on the under surface of the leaf and reached the phloem cells. Much of this work has been confirmed by Murphy in Canada, and by various workers in the United States.

As to the second disease, it was found by Schulz, Folsom and others working in America that potato mosaic was precisely similar to other

mosaic diseases, in that it was highly infectious and was transmitted from plant to plant by means of insects, in this case also by aphides. The American work has since been confirmed by Quanjer in Holland.

Investigations in Britain.

On the publication of these results, the English Ministry of Agriculture took steps to acquaint farmers and growers with the facts, as well as to inform the educational and advisory officers at various institutes. To those who were conversant with previous research, and especially those who had attempted to study the disease in the south of England, the discoveries were illuminating and accounted for many difficulties hitherto unexplained. In some quarters, however, the new views met with prejudice, and in the north especially the idea of leaf-curl being infectious was received almost with incredulity. As will be shown later, there were good grounds for this prejudice. The disease in the north spreads but little, the conditions being unfavourable for the virus-carrying potato aphis. It will be seen, however, in addition, that the English trials fully support the Dutch and American discoveries, and that the very evidence which was put forward to disprove the infection theory only provides it with additional support.

The work carried out in the British Isles on the potato virus diseases is as follows: (1) A series of experiments was carried out in small plots at the Ministry's Pathological Laboratory at Kew in 1920. The results, which confirmed the infectious nature of curl and mosaic,* are summarised below. (2) At the present time two of the Ministry's advisers in plant pathology, Mr. E. Holmes Smith (mycologist) and Mr. Kenneth M. Smith (entomologist) stationed at Manchester University, are carefully going over facts as to insect transmission and ascertaining, by means of insect-proof cages, which particular species of insects spread the disease in this country. (3) The Ministry is seeking, by means of trials carried out at the twelve agricultural centres into which the country is divided, to demonstrate to the farming and gardening community in all parts of England and Wales the seriousness of the disease and the immense importance of obtaining disease-free seed. (4) The Pathological Laboratory of the Ministry, assisted by the inspectors, has conducted a survey on the distribution and intensity of the two diseases in all parts of Britain and is collecting, sifting and summarising all data available. The survey has brought out important points in connection with the seed-potato areas. (5) Research with regard especially to Irish conditions is being carried out in Ireland by Mr. P. A. Murphy.

1) *Infectious Nature of Leaf-curl.*—The following experiments at Kew were planned to demonstrate the infectious nature of leaf-curl.

* Throughout this article the term "mosaic" is used in the broad sense as hitherto understood, although it is probable that, as Quanjer maintains, further research will show that more than one form of mosaic in potatos exists.

Three varieties were used, King Edward, Lochar and President. Seed of the first two were selected in September, 1919, from fields in Scotland which was perfectly free from virus diseases, and healthy seed of President was obtained from Holland through the kindness of Dr. Quanjer. Ten tubers of each variety were employed. Five tubers of each were planted next to Kerr's Pink affected with leaf-curl (and, as was subsequently manifest, with mosaic also) in a small allotment garden near the Herbarium. The remaining five tubers were planted in specially made beds in the Queen's Cottage grounds, this site being chosen to secure, if possible, complete freedom from extraneous infection, *i.e.*, freedom from aphides carrying the virus through having fed on diseased plants. The beds were at least half-a-mile distant from other potatos and were largely encircled with trees, but not shaded.

Although the final results could not be expected till 1921, remarkable effects were obtained during the first year. In all six plots the growth at first was normal and most robust. In the plots grown in the allotment a general attack of aphis was noticeable by June 18th. By July 7th a very marked change had come over the variety, President, three plants out of the five showing the erect, pink, curled foliage (Quanjer's primary leaf-roll), which is typical of this variety.* Shoot by shoot the plants showed the symptoms, and by the end of July only one healthy shoot was left. King Edward commenced to show mosaic in June, and every plant was affected by the middle of July. (This variety was selected because of its well-known rapid deterioration in the Kew neighbourhood. Since it contracted mosaic and not leaf-curl it would appear to be more susceptible to that disease.) In Lochar suspicious leaf-curl symptoms were manifest at the end of June.

In the Queen's Cottage grounds, on the other hand, all the plants, with the exception of President, remained healthy throughout the entire season. No severe aphis infestation occurred, but a few aphides were noted in September. As regards President, one plant (No. 1) developed suspicious symptoms at the end of July, and these became much more marked later, the stems on sectioning showed phloem-necrosis. Part of another plant (No. 4) showed the same symptoms by September 1st. The other three plants remained, as far as could be seen, healthy till cut down by frost in October, but as little new growth took place in September the opportunity for observing further cases of primary infection was not afforded. It may be added that the yield given by the Queen's Cottage plants was about three times that of the allotment plants, but since soil conditions were not identical, and since blight largely destroyed the latter crops in August, the difference can only in part be attributed to the effect of leaf-curl.

* The symptoms of "primary" infection are apparently only visible in certain varieties, President being one of the most marked in this respect.

A selected part of the "seed" from each plant on each of the above plots was saved and planted in 1921 at the Pathological Laboratory grounds (by that date removed to Harpenden). The drought of 1921 and the ill-prepared ground gave the plants little chance to produce either haulm or crop, but the following results sufficiently demonstrate the infectious character of the disease:—

King Edward.—(*a*) (Seed grown on the allotment plot subject to infection from Kerr's Pink.) 14 tubers used, every plant showed mosaic.

(*b*). (Seed grown in Queen's Cottage ground, safeguarded from infection.) 14 tubers used, 12 healthy, 1 curl ? 1 mosaic ?

Lochar.—(*a*) As above. 8 tubers used, every plant showed leaf-curl.

(*b*) As above. 12 tubers used, very much more vigorous than (*a*). ? All healthy.*

President.—(*a*) As above. 18 tubers used. Every plant showed leaf-curl and several showed mosaic in addition. Growth exceedingly poor throughout season and all plants had died down by the end of July.

(*b*) As above. From plant No. 1 (curled September, 1920): 5 tubers used each plant showed leaf-curl. From plant No. 2 (healthy September, 1920):—2 tubers used, slight but distinct curl. From plant No. 3 (healthy September, 1920):—2 tubers used, both healthy. Six tubers sent to Ireland, all healthy. From plant No. 5 (healthy September, 1920):—2 tubers used, both healthy.†

(The tubers from plant No. 4 became mixed and were not used.)

There was again a very marked difference in yield between the healthy and infected plots, but owing to the extreme drought and the state of the ground, the results were abnormal and need not be recorded.

A trial with Kerr's Pink on somewhat different lines gave similar

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* The diagnosis of leaf-curl in this variety is very difficult, owing to a slight inrolling of the normal foliage.

† The results yielded by President require comment. As stated above infection showed in one plant in September, 1920, the 1921 trials confirming this point. The infection in the Queen's Cottage grounds may possibly have been brought by winged female aphides conveyed from a distance by wind, or possibly from a wild solanaceous host. The origin of the infection of plant No. 2 is obscure. Undetected infection in 1920 or aphis attack of the young shoots in the potting shed in the spring of 1921 appear possible explanations.

The infectious nature of curl in President is indicated in experiments recorded in a paper by A. S. Horne published in 1911 (*Journ. Roy. Hort. Soc.*, XXXVI., p. 618). Both this paper and a subsequent one by the same author (*Ann. Appl. Biol.*, I., 2: pp. 183-203, 1914) have been largely overlooked by recent writers on leaf-curl.

results and a mass of less definite evidence, obtained from careful observers in various parts all points in the same direction. Trials on mosaic were planned for 1921, but owing to the hot, dry summer the symptoms were exceedingly difficult to recognise, and owing partly to this and partly to pressure of other work, these were abandoned.

The above experiments give the clue to the abundance of curl and mosaic in allotments and small gardens. Seed of all kinds is in use and there is always an abundance of infective material. "Volunteer" plants, moreover, are prevalent, and act as infection centres. A certain amount of clean northern seed is introduced by the best allotment holders each year, but the crop is promptly infected, the extent varying with the susceptibility of the variety and the nature of the season. Consequently, allotment seed usually "deteriorates" sooner than any other.

Turning to farm conditions in contrast to gardens and allotments, we find evidence of another kind which supports the infection theory. In fields leaf-curl is usually much less prevalent, and "once" or even "twice grown" seed often yields good crops. The explanation is simple. If healthy seed is bought and planted in a field of several acres, the chances of general infection are much less and, unless diseased crops bearing aphides occur in adjoining farms or gardens, the crop is little subject to extraneous infection. Consequently, leaf-curl or mosaic develop more slowly. If the seed is absolutely healthy to start with there is no reason why the disease should appear for several years, and, in fact, magnificent crops of "once grown" Dates and British Queens (both very susceptible to leaf-curl) have been seen in the south without a single infected plant. If, however, as little as two per cent. infection is originally present, after two or three years the infection may be general and the yield as a whole reduced fifty per cent. The rapidity of the spread depends on the intensity of the aphis infestation and this is probably mainly determined by the nature of the season.

(2) *Reduction in Yield.*—The experiments on the effect on yield were carried out in 1921 at the Agricultural Colleges, these institutes being the centres at which the Ministry's Advisers in Plant Pathology are stationed. The object of the experiments was twofold; (i.) to ascertain the loss in yield due to leaf-curl in different parts of the country; (ii.) to demonstrate to the college students and to farmers who visit these centres the seriousness of the disease and the vital necessity of good seed. By carrying out the trials at twelve centres the possibility of any difference in crop being attributable to local conditions was eliminated. The variety selected for experiment was Arran Comrade, the seed being grown in the neighbourhood of Edinburgh, and one cwt. of healthy seed and one cwt. of affected seed

were sent to each college.* The healthy seed was obtained from a field carefully examined and found to be entirely free from disease. The second lot of seed was from a field a few miles distant which was generally, though slightly, affected with leaf-curl. The attack in this field was so slight that some growers would probably have regarded the crop as healthy ; and even by those conversant with leaf-curl it might have been regarded as sufficiently good for seed. The table given below shows how far this view is from the truth.

Trial Centre.	*Yield on Diseased Plot. Healthy Plot=100.*
Bangor.—University College of N. Wales	47·3
Midland Agricultural College, Sutton Bonington ..	48.1
Leeds University.—University Farm, Garforth ..	65.0
Bristol University.—Long Ashton Research Station	36.5
Seale-Hayne Agricultural College, Newton Abbot ..	51.5†
Reading University College	49.6‡
South-Eastern Agricultural College, Wye	46.1
Cambridge.—School of Agriculture	no results
Harper-Adams Agricultural College, Newport ..	79·4
Aberystwyth.—University College of Wales	43·7
Armstrong College, Cockle Park Farm	42·1

There are many details and points of interest in connection with these trials which will be given in the full account shortly to be published (see Journ. Min. Ag.). The above summary is, it is believed fair and approximately correct and shows the immense reduction of crop which occurs even with Scotch seed if infected with leaf-curl.

Susceptibility of Varieties.

It is generally believed that varieties vary very markedly in susceptibility to virus diseases. This is no doubt correct, but the impressions gained by inspection of crops or trials afford little accurate evidence since, as a rule, nothing is known of the past history of the stock. Unless it has been subjected to uniform conditions of infection, the results obviously are not comparable. A record of apparent susceptibility, as shown in the well-known commercial varieties, is maintained by the Ministry, and while many appear to be highly resistant to one or other disease this cannot be accepted till tested by experiment.

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* It was not possible to obtain the two lots of seed from identical land. The healthy seed was grown on reddish loam and the curled on a darker and moister loam. The latter, moreover, was infected with blight, and was not received in such good order as the former. As in most centres the diseased seed was discarded and an equal *number* of tubers used in each plot, this factor should not vitiate the results of the experiment.

† 20 per cent. added for losses due to approximately 25 per cent. misses.

‡ 25 per cent. added for adverse soil conditions.

For this reason no attempt is made to include all varieties in the present paper. The following list indicates those commercial varieties which may often be found in England infected with leaf-curl and mosaic respectively, but whether this implies (1) that a large proportion of the stock became infected in its early history, (2) that it has since been subject to exceptional infection, or (3) that it is actually more susceptible, cannot be stated.

Leaf-curl.

Arran Comrade.
British Queen.
Dargill Early.
Early Puritan.
Epicure.
Kerr's Pink.
King George.
Lochar.
Magnum Bonum.
Majestic.
May Queen.
Midlothian Early.
Ninety Fold.
President.
Sharpe's Express.
Up-to-Date.
White City.

Mosaic.

Arran Chief.
Burnhouse Beauty.
Dargill Early.
Golden Wonder.
Irish Chieftain.
King Edward.
Langworthy.
Tinwald Perfection.

It is probable that no variety is immune from either disease. "Great Scot" is very seldom infected and there can be no doubt that it is highly resistant.

Distribution of Curl and Mosaic in Britain.

Omitting the factor of varietal susceptibility and the question of relative intensity of attack, the two diseases may be taken together. As is now well known, leaf-curl and mosaic may be found amongst potato crops over the whole of England, Scotland and Wales, and it may be said also that it is possible for them to occur in severe form in all parts of these countries. In actual fact, however, we find that, in a general way, both diseases are more abundant in the warmer and drier parts of the country, and that in the northern latitudes, as well as in the higher altitudes, they decrease. The reason for this is due, there can be little doubt, to the relative intensity of the aphis attacks.

In the southern counties of England the diseases may be so severe, both in gardens and under field conditions, that cases of a hundred per cent. infection are not uncommon, with losses estimated at fifty per cent. of crop in fields and even higher in gardens. As one proceeds

northwards the extent of the attack tends to become less,* but wherever the indiscriminate use of home-saved seed has been followed, the presence of curl and mosaic is very general and severe. Allotments in Durham and Northumberland may be found as extensively infected as any in Surrey. Similarly in parts of Wales and the north-west of England, where magnificent crops of potatos are grown, mosaic and leaf-curl in severe form may be found, but they occur less generally, and it is probable that the rapid increase of the disease where home-saved seed is used does not take place to the same extent. This becomes even more apparent in Scotland, and as one approaches the famous seed districts the existence of field after field, even of the most susceptible varieties, entirely free from curl shows how little this disease usually spreads. It is noteworthy, on the other hand, that certain areas in the east of Scotland are not so strikingly free from curl, a phenomenon which is probably due to local soil or climatic conditions being more favourable to the development of potato aphis.

In the extreme north of Scotland there is reason to believe that leaf-curl, and probably mosaic also, does not spread, and, consequently, that under entirely natural conditions they would not be found to occur. There is direct evidence in some localities that where present they have been introduced. Once introduced they remain in the stock, and this doubtless explains the presence of these diseases in parts of Scotland, and is a warning to Scoth growers as to the care necessary when seed is obtained from southern areas. Two specific cases may be referred to.

In certain farms near Invergordon in Ross-shire, "Up-to-Date" has been grown for twenty-five odd years without any change of seed. This variety is exceedingly susceptible to leaf-curl. An inspection of the fields was made in August, 1921. Many acres were examined, on fields well manured and poorly manured, but not a single case of curl was observed. The adjoining fields were planted with "Kerr's Pink," the seed having been obtained from the south of Scotland; here one to four per cent. of curl was manifest. A brief examination for aphides was made and only a few isolated individuals were discovered.† The non-infection of "Up-to-Date" may be explained in three ways: We may suppose (1) that infected crops have not been grown in the vicinity; (2) that aphis infestations have not occurred; or (3) that aphis attacks and a certain amount of infection from other

* Mosaic in the North appears more widely distributed than leaf-curl and may be seen in quantity, especially late in the season, in susceptible varieties. This is perhaps, due to its being more highly infectious. It would seem, however, that in these late attacks the virus does not usually succeed in reaching the tubers, as seed saved from such crops often gives healthy plants.

† It should be mentioned however, that in 1921 potato aphides were much less prevalent than usual, and even in England attacks were comparatively light. The more prevalent potato insects noted in England last season were: Capsid Bugs, Leaf Hoppers (*Typhlocybidae*).

crops have taken place; but these have set in too late for the virus to travel down the stem and along the rhizomes into the tubers. "Kerr's Pink," on the other hand, was introduced as an infected stock; if an aphis attack does not take place or only occurs very late, the disease will remain but will not spread. Any increase or decrease will depend on the method of seed selection. If rogued out, a perfectly clean stock should result and this should remain clean.

The second case is provided by the same variety (Up-to-Date) as grown at Craibstone Experimental Farm near Aberdeen—a station which is well worth a visit by all students of potato virus diseases. It has been stated that if curled stock is sent north, the disease will disappear. This view is not in accord with the facts now known, and the following evidence, kindly supplied by Mr. W. M. Findlay, Superintendent of the Craibstone Experimental Farm, does not support it:—Several stocks of "Up-to-Date" were introduced from the south seven years ago and these have always yielded a very poor crop. For the past three seasons it has been observed that every plant is affected with leaf-curl. After seven years they show no sign of increasing yield or growing out of the disease. On the other hand, a healthy stock of the same variety has been grown on the farm for seven years and at times in close proximity to the last, but has remained vigorous and is entirely free from both curl and mosaic. Change of seed is not necessary in Aberdeenshire and the reason is obvious, virus diseases do not spread. It is clear also that the climate, however favourable, will not eliminate leaf-curl from the progeny of an infected plant. The cases of apparent recovery have no doubt been due to the planting of a *partly* diseased stock from which healthy plants were consciously or unconsciously selected. The Aberdeen results are in agreement with those obtained by Murphy in Prince Edward Island.

From the above it is not surprising that some observers in Scotland regarded Quanjer's discoveries as to the infectious nature of leaf-curl with scepticism, but, in the light of the part played by aphides, their abundance in the south and their relative scarcity in the north, the evidence available is in perfect accordance with the theory.

It will be observed that nothing has been said as to the well-known "seed" areas in Cambridgeshire and Lincolnshire. The object of the Ministry's survey was primarily to ascertain the facts as to distribution, and secondly to discover the conditions determining freedom from disease, and hence the enquiry was continually pushed northwards. There can be no question that the climatic and soil conditions of Lincolnshire and Cambridgeshire are particularly suitable for potato growing, and hence, as explained in the next section, the crop may possibly suffer less from aphis attacks. It is not unlikely that these areas will be found to correspond to those parts of Holland which have proved to be first-class seed potato districts.

The Aphis Attack.

Since it is the presence or absence of aphides and perhaps other insects which determines the spread of curl and mosaic, it is obvious that for a good potato seed area an all-important factor is the degree and period of the annual aphis attack. Under conditions less favourable for aphides the disease spreads slowly, but even here, unless carefully rogued or otherwise selected, it is liable to increase and particularly so in certain seasons. This explains the occasional presence of a considerable amount of curl and mosaic in seed from some of the best seed districts, whether in England or Scotland.

No special systematic work on the potato infesting aphides has yet been carried out in this country. The most usual species appears to be Rhopalosiphon dianthi (=Myzoides persicae, Sulzer) which is prevalent in Holland and apparently also common in America, this being the species which was originally shown by Schulz and Folsom to be a carrier of potato mosaic in Maine. The importance of ascertaining the precise species of aphides which infest potatos lies in the fact that several species have other host plants on which they pass the winter, either in an active or egg state, and the presence or absence of appropriate winter hosts materially affects the intensity of the initial attack in late spring or summer.

The general factors governing the extent and severity of the potato aphis infestation are little understood, though they are now under investigation by Dr. J. Davidson at Rothamsted. There can be no doubt that there are three which are extremely important, viz., climate, soil conditions and, where the winter stage requires another host, the presence of suitable wild or garden plants. Temperature largely governs geographical distribution and, with regard to intensity of attack, Davidson has shown that, in another species, *Aphis rumicis*, a low temperature retards development and reproduction, though an excessively high temperature also has an adverse effect. Temperature, further, is of importance with regard to the date of first migration and consequently of subsequent infestations, a point of vital consequence in determining whether or not the virus will reach the tubers before the crop is lifted or cut off by frost. Wind and rain also doubtless exercise an influence on the degree of intensity manifested. Strong winds over the period of first migration in spring might largely eliminate the season's attack, and again boisterous weather in autumn might adversely affect the migration to winter hosts. The climatic factors are, however, intimately bound up with soil conditions and perhaps especially with that of soil-moisture. It is known that vigorous plants well supplied with water and in congenial soil suffer less from aphis attacks than those less favourably situated. This fact may explain the successful growth obtained in the deep,

porous soil around the basin of the Wash. Davidson has dealt with the relation of cell-sap to aphis infestation and shown that the age of the foliage and the condition of the cell-sap are very important. The physiological condition of the plant and of the sap are known to be materially influenced both by soil and certain climatic conditions.

The presence of winter host-plants may, according to Davidson, be of the very first importance. It will be recalled that many of the Scotch seed districts are surrounded by vast tracts of forest, moorland, or uncultivated land which are probably devoid of suitable hosts, whereas in typically agricultural and horticultural counties very different conditions obtain.

It is possible that the significance of the well-known practice of the using of immature seed lies in defeating the results of the aphis attack rather than in the degree of tuber maturity. This factor must, in many cases, be of very great importance, two to three weeks' earlier lifting safeguarding the tubers from becoming infected, even if the disease had invaded the haulm. Since in all old trials, however, virus diseases were not accurately diagnosed, new series of maturity trials are required, using material certified as absolutely free from disease.

From the above it will be seen that a potato aphis survey would be of great value. It should take into account the various species of aphides involved and their relative abundance. The date of attack, the intensity of infestation, the altitude, soil conditions and character of surrounding vegetation should also be noted. Care should be exercised with regard to any records from gardens and allotments, the conditions of which are of a special nature. If the results obtained were studied with soil and contour maps and with the Meteorological Office returns, valuable information might be acquired. Research by an entomologist is also urgently needed on the part played, if any, by other insects. In 1921, Typhlocybidae in the south of England were very much more prevalent than aphides, and it is possible they also may transmit the disease. Further biological investigations on *Rhopalosiphon dianthi* are required and especially on the winter hosts commonly resorted to. In Holland, Dr. Quanjer has many of these problems under investigation, and marked variations in the prevalence of aphides, and correspondingly in the amount of leaf-curl, have been found to occur in different areas.

Deterioration of Varieties.

The climatic conditions of Scotland are ideal for the growth of the potato and for the production of "seed." It will be obvious, however, that a very material element in the vigour of good Scotch seed is due to the absence of curl and mosaic, and, conversely, that what is spoken of as "deterioration" (or "degeneration") in potatos when grown in England is due to the presence of these diseases.

When a more careful analysis of English crops is made in both fields and small holdings the truth of this statement becomes increasingly apparent. The rapid "deterioration" as ordinarily understood and as manifested in any garden or allotment is due in 80 cases out of 100 to the attacks of mosaic or leaf-curl, or to a combination of both, and the remaining twenty cases appear to be due to other diseases, often those of the same type. When plants are not attacked by virus diseases the ordinary grower would not regard them as "deteriorated." Deterioration as commonly understood therefore is not a physiological phenomenon due to effects of climate or to continued vegetative propagation but to a definite infection. In making this statement it is not denied that potatos, if grown continuously in the south, may, in the complete absence of disease, fall off in yield; but proof of this is wanting since the old records take no accurate account of virus diseases. The fact that in the south mosaic, though present, is in certain seasons recognisable only with great difficulty, makes the investigation of this point additionally difficult. It is, however, maintained that purely physiological deterioration, if present, is of very minor importance and that the rapid and serious decline in yield manifested in such favourites as "Duke of York," "British Queen" and "Up-to-Date" is due to leaf-curl and in such varieties as "King Edward" and "Arran Chief" to mosaic.

The above facts raise the general question of senescence and of deterioration as a result of non-sexual propagation, the potato being one of the best known examples of this theory. As has been shown above, given a suitable climate and absence of the virus-carrying aphides, the potato may, although propagated exclusively by tubers, maintain itself in perfect health for many years. Many old varieties exist to-day and still yield good crops—on the other hand others, such as "Magnum Bonum," are supposed to have deteriorated. Inspection of stocks shows that these latter are usually full of mosaic or leaf-curl. The numerous rhizome, stolon, bulb, and tuber bearing plants grown in "herbaceous borders" show no signs of deterioration, and some of the most persistent and aggressive weeds owe their success almost entirely to vegetative reproduction, *e.g.*, Ranunculus, Convolvulus, Agropyron. Cases of deterioration brought on through lack of sexual reproduction are supposed to occur in many garden plants, such as strawberries and raspberries, but before this can be accepted the pathologist must be called in, and examination made for the presence of disease.

Summary and Practical Conclusions.

The problems dealt with in this paper may be summarised as follows: (1) Such observations and experiments as it has been possible to make tend to confirm the discoveries of Dutch and American workers that

the diseases in question are highly infectious, and that the virus is carried from plant to plant by means of aphides. (2) In the case of leaf-curl, if affected seed is used, a reduction in yield to the extent of 50—60 per cent. may take place in all parts of England, even if this seed is obtained from the very best seed districts. In mosaic the loss is apparently not quite so high, but reliable figures on a field scale are not available. (3) Marked varietal susceptibility is manifested, but owing to lack of uniform exposure to infection, mere observations on crops are not reliable and controlled experiments are required. (4) The distribution of the two diseases in England, Scotland and Wales, is outlined. Both may occur in severe form in all parts, but in the northern and upland areas they are much less prevalent. (5) The comparative freedom from disease in certain districts is believed to be due mainly to the milder attacks or later infestations of the virus-carrying aphides. Susceptible varieties may remain perfectly free from disease in the north of Scotland, whilst introduced diseased stocks of the same variety retain the disease. (6) The relative importance of meteorological conditions, soil conditions, and the presence of other host plants in favouring the aphis attack, is discussed, and the need of research is emphasised. (7) It is shown that deterioration of potatos as ordinarily understood is not a physiological phenomenon but is due to definite infection by a virus disease. (8) The general idea of deterioration as a result of continued non-sexual propagation is criticised, the behaviour of the potato and many other garden and wild plants not supporting it.

The following practical conclusions may be drawn from the above considerations :—

Those breeders and raisers who have long struggled against virus diseases should be on their guard against the introduction of infected seedlings from other areas and should exercise every care that seedlings or choice stock are not grown in proximity to affected plants. Unless required for breeding purposes it would be advisable to destroy all affected plants in the immediate vicinity. As an additional safeguard a good insecticide should be applied at weekly intervals.

The grower for seed has now additional information to assist him in selecting the best seed areas. In most good areas it should be possible by persistent and ruthless roguing to eliminate curl and mosaic entirely. The setting up of a special committee to deal with roguing for diseases and to guarantee the sale of seed free from mosaic and leaf-curl, as has been done by at least one branch of the National Farmers' Union, is a practice which might well be extended. In certain districts early lifting may be of great value in frustrating aphis attacks.

To the ordinary grower for ware, whether large or small, the investigations reiterate the familiar but oft unheeded lesson of the

supreme importance of good seed. Seed from an entirely healthy crop may be saved and grown again, whether once, twice or more times depending on the amount of infection which takes place. A trained observer can, in the case of many varieties, detect infection during the current season and will allot the crop for seed or ware accordingly. In allotments where "deterioration" is known to take place, it is advisable to obtain fresh healthy seed every year, but if this is not possible it is preferable to make a clean sweep every second year than to re-stock every year with fifty per cent. new seed.

Dr. Pethybridge said Dr. Quanjer had referred to several types of mosaic and he and Mr. Murphy had mentioned Curly Dwarf. Curly Dwarf is often claimed to be one of the last stages in mosaic. He had cultivated Curly Dwarf for several years and found that the tubers became very small, ultimately often no larger than green peas, and then died right out. It had been suggested that these diseases were the result of malnutrition, but experiments did not confirm the suggestion and Dr. Pethybridge gave details of some experiments.

Mr. Monak thought soil physiology was an important matter in connection with these diseases and would look to soil sterilisation as a possible means of combating them.

Dr. Salaman asked if any experts could give their experience with miniature tubers. Mr. Cotton's remarks on virus entering tubers suggested there might be a time before which the tubers were free.

Mr. Cuthbertson said Mr. Sutton had proved that the produce from badly curled plants, if lifted immature, gave healthy crops. While Dr. Quanjer was speaking, he visualised a whole army of inspectors examining their crops, but the conference had shown how necessary careful roguing out of diseased and possibly diseased plants was in seed growing and he felt sure the practical growers would take the matter in hand and keep that great army at bay.

Mr. Buchanan found that small (second-growth) tubers gave him less leaf-curl in the crop than did mature large tubers used as seed. He had used the Woburn Bordeaux mixture with success in spraying against blight.

M. Et. Foex pointed out that during a visit paid to one of Professor Quanjer's experimental fields at Wageningen in Holland, he had selected some specimens with the intention of trying to verify the existence of a correlation between leaf-curl and phloem necrosis.

The material he collected came from several different varieties, and was selected from healthy plants or from plants severely attacked either by leaf-curl or by some other disease.

Each specimen consisted of a piece of petiole and was placed in a bag bearing a number of which he alone knew the signification.

M. Quanjer cut these petioles and examined them at his leisure. He afterwards sent him the results of his examination. To indicate the degree of severity of the phloem necrosis he used a scale of numbers from 1 to 10. In the account given the number rises with the accentuation of the phloem necrosis (Zero (0) indicates a plant free from the disease).

Nos.	Variety.	Number in Expt. Field.	Observations.	Scale No. given by M. Quanjer.
6	McCormick (American) ..	729	Curled ..	8
3	Koh-i-nohr (Dutch)..	594	Curled	5
4	Gloriosa (German) ..	253	Curled	9
8	Parnassia (German)..	94	Curled	8
20	Lembkes auf der Höhe (German)	89	Curled	7
7	Lembkes auf der Höhe	89	Healthy	0
17	Bleue de Zélande .. (Dutch)	58	Curled	6
18	Kruisling (Dutch) ..	60	Curled	5
10	Duke of York .. .. (British)	739	Not true leaf curl but marginal roll	0
19	Bravo	728	Crinkle	0
5	Bravo	727	Duke of York mosaic	0
16	Paul Krüger (Dutch)	G. 416 II.	Aucuba mosaic	0
2	Kruisling	138	Healthy	0
15	Bleue de Zélande ..	239	Healthy	0
9	McCormick	779	Healthy	0
14	Koh-i-nohr	587	Healthy	0
11	Parnassia	283	Healthy	Only in one place strongly, but no typical necrosis and the other phloem vessels healthy.

From this table it could be deduced that there exists a remarkable correlation between leaf-curl and phloem necrosis. Plants showing other maladies than leaf-curl, *e.g.*, mosaic, crinkle, Duke of York mosaic, aucuba mosaic, etc.) were not affected by phloem necrosis.

The result of this test, to which M. Quanjer gladly submitted, was still more interesting in view of the fact that the correlation between phloem necrosis and leaf-curl was still much disputed, especially by certain German authors, such as R. Schander and W. V. Tiesenhausen as well as by F. Esmarck.

As to the characteristics of phloem necrosis of the potato plant, M. Foëx's conclusions were that generally the disease first showed itself in the angles of the cell walls, which swelled and turned yellow or brown. The thickness thus produced might extend to the nudole of one or of several adjacent partitions and spread little by little to the neighbouring cells.

Phloem necrosis was a process of pectic degeneration which was not pushed far enough to produce a true gum flux as is manifested in the phloem of so many acacias. It was probable that the arrest of the pectic swelling and the hardening of the necrotic elements could be attributed to the early appearance of lignin and of suberin. The wood and cork formation appeared to be particularly early in the membranes that remained there.

We must remember that lignin was often associated with the production of gum in wounded tissues, in certain reactions in the process of healing over (Tison) and also in cells that have undergone certain parasitic actions (Ducomet). The association of lignin and suberin was frequent in normal cork formation and in certain products of the formation of cicatrice (scarring over ?). Lignin appeared fairly often in broken down cell-walls, especially in the case of cells parasitised by fungi with subcuticular mycelium (Ducomet). Mangin had demonstrated the importance of pectic substances in the process of cutinisation and Ducomet considered that these substances played an analogous role in the phenomenon of lignification. Moreover, the identity of composition which, according to Cross, existed between the pectin of the white currant and the substance of a lignocellulose type, allowed us to suppose that the substances that belong to this latter group, *i.e.*, lignocellulose, could succeed to those of the former.

The series of transformations undergone by the necrotic membrane of the phloem, the production of pectic matter to begin with, of lignin and suberin subsequently, did not relate to a new phenomenon ; but the very early appearance of lignin and suberin and the very strict localisation of the disturbances gave a special aspect to phloem necrosis.

Dr. Quanjer in replying suggested that international experiments would be most valuable, *e.g.*, we might compare with advantage stocks raised in the south of Holland with those raised in southern England. The diseases are difficult to describe, but easy to recognise in the field and his Government had commissioned him to invite English growers and breeders to see the experimental plantations at Wageningen in May or in June next, when the symptoms will be most evident. He said that in Holland a great army of inspectors was not needed, for the farmers readily sought and acted upon the advice of scientific men in these matters. They themselves carried out the work of obtaining healthy stocks because they were alive to its importance. The method of selecting a single healthy plot and surrounding it with other healthy ones to avoid contagion had been followed in Friesland, so that now large fields were filled with the healthy progeny of that individual. He asked whether Mr. Findlay would be willing to co-operate in such experiments as he had suggested and Mr. Findlay agreed.

*NEW WORK ON POTATO DISEASES IN AMERICA.

W. A. Orton, U.S. Department of Agriculture.

In attempting to present to an English audience a general view of potato pathology in America, attention should be drawn at the start to the extreme diversity of climatic conditions in different parts of our country and the marked dissimilarity between European conditions and ours. The cool summer and abundant rainfall which best suit the potato are found only in the northern tier of states, and particularly in Aroostook County, Maine, and the adjacent Maritime Provinces of Canada. The greater part of the United States lies south of the potato belt. The high summer temperatures which promote the development of maize and sweet potatos are unfavourable to the development of the Irish potato, which in these regions is grown as an early spring or as a late fall crop.

It is characteristic of American agriculture also that the cultivation of potatos for market purposes is highly specialised and concentrated in a limited number of producing centres, such as Aroostook County, Maine; Hastings, Florida; Norfolk, Virginia, and other Atlantic Coast points; Greeley, Colorado; and Stockton, California. Only in the Northern States, from New York to Minnesota, is the potato a state-wide general farm crop grown for market rather than merely for home use.

As a consequence of this situation, potatos are required to be shipped long distances, principally by rail, to the great markets of the north-central and eastern cities. This movement in car loads and train lots begins in Florida in March. A constant stream rolls northward from the Carolinas, Virginia and New Jersey until September, when the main northern crop starts to market. In the same way Louisiana, Texas, and later, Oklahoma and Missouri supply the north-central cities, and potatos from California, Colorado, Idaho and Washington move in a general easterly and south-easterly direction. The southern districts, which furnish the early supply, become consumers of northern potatos immediately after their own crops are harvested, as the earliest potatos are not only high priced but too perishable to be conserved in the district of production.

The potato disease conditions which are typical American problems have a close relation to these diverse climatic conditions and to the necessity for long-distance shipments of the crop. It is only in the extreme North-east that late blight (*Phytophthora infestans*) is generally prevalent. The region of most constant occurrence of this disease

* This paper was received too late for the Conference.

is Maine and the Maritime Provinces. It is common in the North Eastern States above a line drawn from New York to Cleveland and in seasons of cool, wet summers it develops in Minnesota and southward in the Appalachian Mountain region to the Carolinas. This latter section is noteworthy on account of the occurrence there of a distinct biological strain of *Phytophthora infestans* on tomato, which is shown by the recent work of Giddings and Berg* to be much more destructive to the latter crop than is the potato Phytophthora, which also occurs in the same region.

These diseases were uncommonly prevalent in 1921, while in the north-eastern part of the country the warm, dry summer reduced the amount of late blight to the lowest point for many years. Not much of distinct importance has been contributed to the Phytophthora question in the last two or three years. Control of the disease by spraying is somewhat more general and there has been a distinct revival of interest in dusting, a practice which has for a generation been tried with more or less ineffective results. There have, however, been improvements in the technique of preparing dust fungicides and in the development of high-power machines for applying these dusts which support hope that our growers may eventually dispense with the heavy and laborious, and consequently expensive, method of distributing fungicides in water and substitute therefor a material such as the Sanders' dust.† The efficiency of such dust treatment in seasons of extreme prevalence of Phytophthora is, however, yet to be demonstrated.

It may interest potato growers in England, where Burgundy mixture, or soda-Bordeaux, is much used, to know that practically all the American trials indicate the superiority under our conditions of standard lime Bordeaux.

Malnutrition Troubles.

The war shortage of potash developed most interesting pathological phenomena, the first of which was a potash hunger. Potato plants in numerous eastern fields, from Maine to Virginia, developed a downward curling of the leaf margins accompanied by a bronzing and later a browning but not a yellowing of the foliage. Death of the leaves and sudden collapse of the stems at the ground level followed. Fungi of parasitic habits appeared at and above the point of collapse. In Maine and elsewhere the disease appeared to be correlated with certain soil types and was most marked in periods of hot, dry weather. Later, after a supply of potash had been drawn from the Searles

* Giddings, N. J., and Berg, Anthony. A Comparison of the Late Blights of Tomato and Potato. Phytopathology 9, 209–210. May, 1919.

† Sanders, G. E., and Kelsall, A. A Copper Dust. Proc. Entom. Soc., Nova Scotia 4 (1918), 32–37. 1919.

Lake district in California, a new disease developed, which was shown to be due to the occurrence of small amounts of borax in the fertiliser.*

Soil Fungi.

Since the principal areas of the United States lie in districts where the summer soil temperatures are higher than the potato prefers, we have to deal with the problem of root parasites to a great and increasing extent. Rhizoctonia is almost universally prevalent and *Sclerotium rolfsii* is frequent in the South. Species of Fusarium present complex and extremely difficult problems of potato culture. We are coming to realise more and more, since the work of MacMillan,† that we have to deal primarily with a condition of general soil infection and that the planting of healthy seed is by no means an insurance of a healthy crop. Crop rotation methods have yet to be worked out, the influence of irrigation and cultural technique studied, and more experiments with prevention of infection by planting whole, uninjured tubers tried. Fusarium blight is one of the most widespread and prevalent diseases in this country. In the Pacific North-West, however, McKay‡ has confirmed the writer's findings that the prevalent form of wilt there is due to *Verticillium albo-atrum*, a condition clearly based on the relative reaction of these two genera to temperature, Verticillium having an optimum growth point distinctly lower than Fusarium.‖ We used to think that stem-end vascular discoloration indicated infection with Fusarium or Verticillium and was to be interpreted as cause for rejection of the affected tubers. Such a general conclusion has been greatly unsettled by an analytical study by Dr. Edson,§ which revealed the occurrence in discoloured tubers of many other species of fungi. "In the material studied, vascular discoloration of stem-end tissues of Irish potato tubers was not found to be proof of the presence of parasitic fungi. Discoloured bundles were often sterile and fungi were frequently isolated from tissues which appeared normal. The organisms recovered, in the order of their greatest frequency, were Fusarium, 720; Alternaria, 615; Bacteria, 241; Verticillium, 147; Penicillium, 104; Colletrichum, 91; Rhizoctonia, 12; miscellaneous, 87. Out of 3,203 plantings, all but

* Schreiner, Oswald, Brown, B.E., Skinner, J. J., and Shapovalov, M. Crop Injury by Borax in Fertilizers. U.S. Department of Agriculture Circular 84. Feb., 1920.

† MacMillan, H. G. Fusarium Blight of Potatos under Irrigation. Journ. Agricultural Research 16, 279–303. March, 1919.

‡ McKay, M. B. Transmission of Some Wilt Diseases in Seed Potatos. Journ. Agricultural Research 21, 821–847. Sept., 1921.

‖ Edson, H. A., and Shapovalov, M. Temperature Relations of Certain Potato Rot and Wilt Producing Fungi. Journ. Agricultural Research 18, 511–524. Feb., 1920.

§ Edson, H. A. Vascular Discoloration of Irish Potato Tubers. Journ. Agricultural Research 20, 277–294. Nov., 1920.

161 of which were from discoloured tissues, 1,352 gave no growth. The field trials indicate that neither vascular discoloration nor fungus invasion of the tissues of the mother tuber is a guarantee of disease in the resulting plants, nor is their absence a guarantee of health. The soil, and not the tuber, appeared to have been the more potent source of disease. Stem-end pieces yielded higher percentages of disease than eye-end pieces, evidently because the stem end is endowed with less physiological resistance. The plants showed a marked capacity for recuperation, which varied with the variety, with the environment and with the interaction of the two."

Tuber Rots.

The causes of tuber decay with which we have to deal also bear a marked relation to climatic conditions. In addition to Phytophthora dry rot, we have minor losses in the North-East from *Fusarium cæruleum*, in much the same way that this form of dry rot has been shown to occur in England, but in the North-Western States there is a more active parasite, *Fusarium trichothecioides*, which causes the rapid destruction of wounded tubers and possesses the ability to develop at a very low temperature. We find also that tuber decay is caused by several other species of Fusarium, including *F. oxysporum*, *F. radicicola*, *F. discolor* var. *sulphureum*, and we do not know how many more.

Potato Leak.

The rapid decay of early harvested potatos, due to *Pythium debaryanum* and *Rhizopus nigricans*, long known to occur in California, has been found, since we have watched the markets more closely, to occur in several other sections. It is, however, limited in its ability to attack potatos, in that it can only infect wounded tubers under conditions of rather high temperature. Some interesting studies on the parasitism of Pythium have been made by Hawkins and Harvey,* which are of interest in showing that mechanical pressure is the most active agent in producing infection. These authors succeeded in photographing growing hyphæ of Pythium in their progress through potato tissues by means of a motion picture apparatus, so that the growth of the fungus, the pressure against the cell wall, the bending back of the hyphæ and its sudden push forward after penetration are graphically shown by the cinema. We are realising more than heretofore the very extensive rôle that Pythium plays as a plant pathogene, on peas as well as potatos, and, as indicated by

* Hawkins, Lon A., and Harvey, R. B. Physiological Study of the Parasitism of Pythium Debaryanum on the Potato Tuber. Journ. Agricultural Research 18, 275–297. Dec., 1919.

Carpenter, on sugar cane and pineapples in Hawaii.* We may reasonably expect that Pythium will be found to be one of the principal root parasites in other countries.

Bacterial Potato Diseases.

Black-leg has diminished in prevalence in the Eastern States, on account of control measures instituted largely as a result of the potato seed certification movement, but the disease has been found to prevail in the West, where it was for a time confused with Fusarium injury.† A study of the pathological anatomy of this Western black-leg has been made by Artschwager.‡ "Potato plants affected with black-leg show an increase in strongly lignified vascular tissue and a transformation of part or most of the parenchyma cells of cortex and pith into sclereids. Associated with black-leg is the occurrence of protein crystals, especially in the cells of the leaves. Under normal conditions protein crystals have been observed only in the peripheral cell layers of the cortex of the potato tubers."

Soft rot bacteria, resulting from high temperatures and excessive humidity, are particularly characteristic of summer shipments from the South.

Potato Wart.

The outstanding features of the wart situation in the United States are limited distribution to a few mining villages in a line extending from Eastern Pennsylvania to West Virginia.‖ The most thorough surveys have revealed no infections outside of this area and only a few more in the general region, particularly in Western Maryland. We find that we have in cultivation several very excellent varieties which are quite immune to wart. The only disquieting feature of the situation therefore is that none of these varieties belong to the Rural New Yorker group, which on account of its resistance to summer heat, is the most widely cultivated potato variety from Western New York to Minnesota. The spread of wart to this great potato region would therefore find us still unprepared.

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* Carpenter, C. W. Morphological Studies of the Pythium-like Fungi Associated with Root-rot in Hawaii. Expt. Sta. Hawaiian Sugar Planters Association, Bot. Ser. 3, 59–65. Aug., 1921.

Carpenter, C. W. Pythium in Relation to Lahaina Disease and Pineapple Wilt. Hawaii Plant Rec. 23, 142–147. Sept., 1920.

† Shapovalov, M., and Edson, H. A. Black-leg Potato Tuber Rot under Irrigation. Journ. Agr. Research 22, 81–92. Oct., 1921.

‡ Artschwager, Ernst F. Pathological Anatomy of Potato Black-leg. Journ. Agr. Research 20, 325–330. Nov., 1920.

‖ Lyman, G. R., Kunkel, L. O., and Orton, C. R. Potato Wart. U.S. Department of Agriculture Circular 111. Oct., 1920.

Potato Mosaic.

The mosaic disease of potatos is perhaps our greatest pathological problem. It occurs not only in the North Eastern States, but to a rapidly increasing extent throughout the West, and will require still more research and energetic application of control measures, with the assistance of the seed certification movement, to bring it under control. In the recent investigations of mosaic by Schultz and his associates* particular attention was given to phases of this problem relating to distribution, characteristic symptoms under different climatic conditions and on different varieties, nature and means of transmission and control measures, including studies of resistance and susceptibility of different varieties, elimination of diseased plants by rogueing, isolation of healthy plants from mosaic stock and spraying for aphids and other possible carriers of this disease.

Mosaic of Irish potatos is characterised by mottling produced by the presence of irregular light green areas on the leaves. Considerable variation in the colour, from a slight fading of the green to a more distinct yellow, may obtain. In fact, the line of demarkation between the light green patches and the dark green areas of a mosaic leaf frequently are very indistinct.

Mottling is very materially modified by certain environmental conditions; it may not be discernible on mosaic plants of the same stock grown in different localities. Under such conditions a part of the stock grown in one section, usually the more northern section, may show distinct mottling, while a part of the same mosaic tuber unit in a section further south may be free from mottling during the same season. When such stock is grown under conditions favourable for the development of this symptom, the following season the characteristic mottling again appears. This variation in mottling also may obtain on the same plants during a single season in the same locality; in this connection it has been observed that all mosaic plants may not show mottling until the plant is fully half grown. Furthermore, in a warm and relatively dry season mottling on all mosaic plants may not develop in a locality where it ordinarily appears on such stock under cool and moist conditions. Similarly, mosaic is much less distinct under dry land culture than in the irrigated areas.

In more advanced stages of this disease, in addition to mottling, the foliage usually is wrinkled or ruffled and often curled downward. The entire plant frequently is dwarfed. These characteristics make it possible to detect mosaic plants when mottling is absent or indistinct.

* Schultz, E. S., Folsom, Donald, Hildebrandt, F. M., and Hawkins, L. A. Investigations on the Mosaic Disease of the Irish Potato. Journ. Agr. Research 17, 247–273. Sept., 1919.

Schultz, E. S., and Folsom, Donald. Transmission of the Mosaic Disease of Irish Potatos. Journ. Agr. Research 19, 315–337. July, 1920.

On certain varieties, like the Rural types, mosaic is manifested very generally by wrinkling, curling and dwarfing.

In view of these variations in the symptoms of mosaic, a correct diagnosis in slight cases of this disease is very difficult; in fact, it is altogether possible to designate such plants as healthy under conditions unfavourable for mottling. Such cases obtain with all mosaic stock. Plants becoming infected during the latter part of the growing season, when further growth has practically ceased, will not disclose any of the macroscopic symptoms of this disease. The percentage of mosaic plants in such stock can be ascertained only in their progeny grown under conditions favourable for the development of the characteristic symptoms of this malady.

Observations on the occurrence of mosaic of Irish potato in this country indicate that it is present in practically every state in the United States and in Canada. It is found in all the seed producing States, from which it is readily distributed through the tubers from diseased plants to other parts of the country.

Reduction in yield appears in connection with mosaic plants. The extent of this reduction depends upon the severity of the disease and upon the growing conditions. It appears that in the southern sections where climatic conditions are less favourable than in the northern districts, the yield reduction may vary from 10 to 75 per cent., whereas in the northern and more favourable potato growing sections reductions in yield rarely exceed 30 per cent.

Transmission of mosaic of Irish potatos through the tubers was observed when this malady was first recognised (1912–13) in this country. Recent investigations have confirmed this observation and have established the fact that transmission of this disease can be effected by tuber and stem grafts, by introduction of juice from diseased plants into the healthy foliage by means of mutilating the leaves by rubbing, and by means of aphids, *Macrosiphum solanifolii* Ashmead, and *Myzus persicæ* Sulz.

In these transmission studies the possible relation to the spread of potato mosaic of the seed-cutting knife, contact of mosaic foliage with healthy foliage, contact of cut seed pieces from mosaic stock with those from healthy plants, soil on which mosaic plants were grown the previous season, Colorado potato beetle (*Leptinotarsa decemlineata* Say.) and flea beetles (*Epitrix cucumeris* Harris) were considered. In each of these tests, however, negative results were obtained.

From the investigations of the transmission of potato mosaic it is evident that aphids and probably other similar insects are the most effective natural means in the transmission of this potato malady.

Inter-varietal infection experiments by means of the mutilation method have disclosed the fact that potato mosaic can be transmitted

among the common commercial varieties, Green Mountain, Irish Cobbler and Bliss Triumph. Infection experiments in which aphids were allowed to disperse freely between all-mosaic Bliss Triumph foliage and healthy plants of Green Mountain, Irish Cobbler, Rural New Yorker and Rose Four varieties confirmed inter-varietal susceptibility obtained by means of inoculation by mutilation. In these infection tests apparently distinct varietal response obtained in case of the Rural New Yorker variety, resulting in a considerable percentage of curly-dwarf plants.

In these infection experiments by means of aphids and from observation in commercial fields in the northern potato sections, the Irish Cobbler variety shows a lower percentage of mosaic infection than such leading commercial varieties as the Green Mountain, Rural New Yorker, Bliss Triumph and Rose Four. In view of these apparent variations in the percentage of mosaic plants in certain commercial varieties, investigations on the nature and causes of these variations are in progress.

Investigations on the production of mosaic-free potatos include: (1) elimination by roguing mosaic plants from the seed stock; (2) roguing mosaic plants and spraying for aphids and other possible insect carriers; (3) isolated seed plot, roguing and spraying of isolated plot; (4) production of resistant varieties by selection and breeding.

Tests on elimination by roguing mosaic plants from seed stock grown near non-rogued stock where aphids are numerous have established clearly that such a procedure tends to reduce the percentage of mosaic as compared with non-rogued stock. However, under such conditions it has not been possible to secure mosaic-free stock. The percentage of mosaic plants in such roguing tests fluctuates with the fluctuation of aphid infestation. Hill selections under such conditions are not reliable in view of the fact that mosaic symptoms on newly infected plants may not be discernible before the appearance of the foliage in the second generation.

Roguing mosaic plants and spraying for aphids with nicotine sulphate according to the spray formula, $\frac{3}{4}$ pint of "Black Leaf 40" to 50 gallons of Bordeaux mixture, commonly recommended for the control of aphids, did not produce mosaic-free stock. Apparently a sufficiently large number of aphids survived to transmit mosaic freely.

In certain northern potato growing sections, where aphids were less numerous and where a lower percentage of mosaic plants occurred than in the foregoing tests, it has been possible merely by roguing to reduce the percentage of mosaic plants to 2 per cent. Under such conditions, where fields were isolated from diseased stock, it has been possible to produce mosaic-free stock simply by roguing.

In view of these results it seems quite essential, in order to secure and

maintain mosaic-free stock from susceptible varieties, that the seed plot for the production of such varieties should be isolated as far as possible from mosaic plants and that all mosaic plants should be eliminated by roguing such a plot at least three times during the season. In roguing such plots all mosaic foliage, including seed pieces, should be removed carefully from the plot, so as to eliminate all possible sources of infection. In order to determine whether or not it is possible to obtain more effective results by spraying such an isolated plot for the control of aphids, further studies in this connection are in progress.

Since the production and maintenance of mosaic-free stock from susceptible varieties presents such a complicated problem, it would be especially desirable to obtain resistant or immune varieties, either through selection or breeding. This phase of the problem on mosaic of potatos also is under investigation.

Leaf-Roll.

In the investigations on leaf-roll of Irish potatos, (*) a plan similar to the one followed in the study of mosaic of potato was observed. Special attention was given to distribution and economic importance, nature and means of transmission and control measures, including roguing and tuber selection.

The principal macroscopic symptom of leaf-roll is the upward rolling of the leaves in such a manner that the mid-rib remains at the middle of the trough thus formed. Rolling may occur throughout the entire plant or it may appear only at either the base or apex of the stalk. Plants from tubers which became infected during the previous season show rolling of the lower leaves first, the rolling usually being very apparent at blossoming time, frequently followed by rolling of progressively higher leaves later in the season until all may be rolled. Plants becoming infected late in the season may show rolling in the upper leaves only. Other macroscopic characters of leaf-roll include rigidity ; leathery textures ; light green, yellowish, reddish or purplish discolouration of the affected leaves ; dwarfing of the vines, which usually remain erect and rigid ; shortness of stolons ; reduction in the number and size of tubers ; and rigidity or woodiness of the tubers. Some of these symptoms may not always be present. The leaf-roll here considered must not be confused with the flaccid, wilted condition of rolled leaves on plants affected with wilt disease. Asymmetrical rolling of the upper leaves due to insect injuries can hardly be mistaken for the symmetrical rolling of the leaves in leaf-roll of potato. The presence of underground stem lesions caused by Rhizoctonia help to distinguish this type of leaf-roll from the non-parasitic type.

* Schultz, E. S., and Folsom, Donald. Leaf-roll, Net-Necrosis and Spindling Sprout of the Irish Potato. Journ. Agr. Research 21, 47–80. April, 1921.

Leaf-roll in connection with black-leg infection is characteristically accompanied by rather pronounced yellowing of the entire plant and the blackened underground stems further help to diagnose this type. There is a leaf-roll due to drought and a non-parasitic type of leaf-roll due to excessive moisture may resemble very closely the type of leaf-roll here considered. On this type, however, the leaves on the entire plant may become rolled at any time during its development. The foliage is not as stiff and rigid and the rolling is limited to conditions where excessive soil moisture obtains. With a knowledge of these symptoms due to different causes for leaf-roll, it is usually possible to distinguish such cases from the leaf-roll of potato considered in this paper.

Extended surveys in this country have disclosed that leaf-roll of potato occurs in all the seed-producing districts in the North as well as in the potato growing sections in the South. It occurs less generally, however, in the seed producing sections than mosaic of potato. Estimates from these surveys show that the percentage of infected plants may range from 1 to 95. Considerable losses obtain where this malady occurs on a high percentage of the plants, since affected plants frequently produce tubers which may be greatly reduced in size and numbers.

Transmission of leaf-roll through the tubers was noted several years ago, soon after the discovery of this disease. More recent investigations on this malady have disclosed the fact that transmission can be secured by means of tuber and stem grafts and through the agency of aphids.

Experiments in field and greenhouse have clearly established the fact that the same genera of aphids which transmit mosaic of potato also are capable of transmitting leaf-roll. As with mosaic of potato, aphids and possibly similar insects apparently are the most effective natural agents in the transmission of leaf-roll of potato.

In the studies on macroscopic symptoms of leaf-roll it was found that in certain cases a reliable diagnosis for leaf-roll was possible from examination of the tubers. Tubers having necrosis of the phlœm so that a macroscopic examination reveals a discoloured network, which the symptomatic term " net necrosis " describes very adequately, invariably develop plants with leaf-roll. In these observations it was noted that net-necrosis did not appear in stock free from leaf-roll, that it does not appear in all tubers from leaf-roll plants ; that in certain varieties it appears to be inheritable, in which case the lighter weight tubers show it more frequently ; that recency of leaf-roll infection may determine the development of net-necrosis within a given variety ; and finally that net-necrosis resulting from recent leaf-roll infection appears more common in a certain strain in tubers from plants grown near leaf-roll hills, and in such cases is less common in the lighter

weight tubers. In view of this relation of net-necrosis to leaf-roll, transmission and control are closely concerned with both.

Elimination of leaf-roll plants by means of roguing, supplemented by discarding small tubers for one season, has resulted in the production of stock free from leaf-roll in North-eastern Maine. Since field experiments disclosed the fact that the percentage of leaf-roll plants increased with the closer proximity of such stock to all leaf-roll stock due to transmission by aphids, it is essential that seed stock should be grown in a plot isolated from leaf-roll plants. By removing all leaf-roll plants from such a seed plot before a general aphid infestation obtains, the opportunities for transmission will be greatly minimised. Elimination of leaf-roll plants by means of roguing alone resulted in much better control than in the case of mosaic of potato. Whether this is due to less prevalence of diseased plants or to less susceptibility under the existing conditions of aphid infestation remains to be determined by further investigation.

EXHIBITION OF THE NATIONAL POTATO SOCIETY.

The National Potato Society held its annual Exhibition in the Royal Horticultural Hall during the Potato Conference, on Thursday and Friday, the 17th and 18th November, 1921. The Exhibition was opened by Lt. Colonel the Rt. Hon. Sir Arthur Griffith Boscawen, M.P., and contained, besides the competitive classes and nurserymen's groups, the following scientific exhibits:

EXHIBITS IN SCIENCE SECTION OF POTATO EXHIBITION AND JUDGES' AWARDS.

1.—H.M. Ministry of Agriculture.

a. Preserved specimens and illustrations of potatos attacked by wart disease.

b. Models of tubers and other parts of potato plants to show the prominent symptoms by which different diseases of potatos may be recognised.

c. Dishes of varieties of potato susceptible to wart disease.

d. Dishes of varieties of potato immune from wart disease.

e. Lists of principal synonyms of chief potatos immune from wart disease.

f. Dishes of old varieties of potato, such as Leathercoats, Yam, Silverskins, Gawkies, Paterson's Victoria, etc.

g. Dishes of American varieties of potato.

h Photographs of operations connected with potato growing, potato machinery, etc.

2.—M. Aumiot, of Villeurbanne (Rhone).

A series of tubers obtained by crossing to illustrate the following rules which the exhibitor believes he has established:

a. The greater the difference in type between two parents the stronger the offspring.

b. The hybrid shows characters of both parents but those of the pollen parent are predominant.

c. A seedling produces tubers which are nearly identical with one another.

d. In some cases the seeds from a single berry give seedlings differing greatly from one another in morphological characters, productiveness and season.

e. The marked characters of a parent are more marked in the seedlings.

M. Aumiot also drew attention to a case of a cross (Beurre Bolivienne 10bus) which produced 100 seedlings identical with one another and having the very large, vigorous foliage, shape and rosy skin of the latter, combined with the yellow flesh of the former parent.

3.—Mr. McKelvie, of Lamlash. A series of tubers showing different sports of potato, Arran Victory, in illustration of his paper on sporting in potatos.

4.—Dr. Quanjer of Wageningen. (Silver Lindley Medal.) Carefully and accurately coloured drawings of leaf-curl, mosaic, crinkle and related diseases of potato foliage.

5.—Dr. Salaman of Barley, and Capt. Lesley of the Plant Breeding Institute, Cambridge. (Silver Lindley Medal.) Specimens, diagrams, and drawings illustrating certain facts of potato genetics, *e.g.* :

a. The relation between prone and erect habits and the histological characters of the stem connected with them.

b. The relation of simple and compound inflorescences.

c. The segregation of colour factors in flower and tuber of potato and their recombination.

[Tuber and flower colour appear to be inherited separately, though some tints of flower are associated with certain types of tuber colour.]

This exhibit also illustrated a mutation in Golden Wonder, where a wedge-shaped segment of tuber lacking the typical brown coloration of that variety gave clear-skinned progeny.

6.—Prof. Seton and Mr. Millard, of Leeds University. (Silver Lindley Medal.) Specimens and diagrams illustrating the cause of common scab of potatos and its prevention. Ten strains of the bacterium (*Actinomyces scabies*) which is the cause of the trouble were shown, with photographs illustrating their characteristics. The examples showed that lime increases scab, while green manuring decreases it.

7.—The Scottish Society for Research in Plant Breeding. Potato tubers with their pedigree, illustrating in the main the work of the late Dr. John Wilson in raising his excellent varieties, Bishop, Templar, etc.

8.—Dr. Pethybridge, of the Department of Agriculture and Technical Instruction for Ireland. (Silver-Gilt Lindley Medal.) Photographic illustrations of potato diseases, including blight, verticillium attack, black leg, wilt and others; tubers showing the comparatively new disease called pink-rot.

9.—Miss Breeze, B.Sc., Plant Breeding Institute, Cambridge. (Certificate of Appreciation.)

a. A series of tubers (1, 2, and 3 years from seed) raised by crossing Up-to-Date and Leinster Wonder.

b. Drawings (coloured) illustrating the exhibitor's researches upon anther degeneration in the potato.

10.—Prof. V. H. Blackman, Imperial College of Science, South Kensington. (Certificate of Appreciation.) Dr. Curtis's drawings of the life history of the organism of wart disease, synchytrium endobioticum.

11.—Department of Agriculture for India. Specimens and herbarium specimens of Indian diseases of potatos.

12.—Messrs. Dobbie & Co., of Edinburgh. (Silver Lindley Medal.) Photographic illustrations showing leaf, stem, and tuber characters, with notes on colour, etc., of twenty-seven varieties of potato, life size.

13.—Dr. W. G. Smith, East of Scotland College of Agriculture, Edinburgh. Models of potatos made for the Great Exhibition of 1851, forming part of the exhibit made on that occasion by Messrs. Lawson of Edinburgh.

AWARDS TO THE SCIENTIFIC EXHIBITS

SILVER-GILT LINDLEY MEDAL.

To the Department of Agriculture and Technical Institute for Ireland for illustrations of Potato Diseases.

SILVER LINDLEY MEDAL.

To the University of Leeds for an exhibit showing causes of, and treatment for, Scab.

To Dr. Salaman and Mr. Lesley for illustrations of Potato Genetics.

To Messrs. Dobbie & Co. for Photographs showing varietal differences of Potatos.

To Potato Research Laboratory, Wageningen, Holland, for illustrations of Mosaic and Leaf-Curl diseases.

CERTIFICATE OF APPRECIATION.

To Imperial College of Science for work on Life History of Wart Disease organisms.

To Miss Breeze for work on Potato Anther degeneration.

THE FOLLOWING AWARDS WERE ALSO MADE TO GROUPS OF COMMERCIAL VARIETIES OF POTATOS.

GOLD MEDAL.

To Messrs. Dobbie of Edinburgh.

To Messrs. Sutton of Reading

SILVER KNIGHTIAN MEDAL.

To Messrs. E. Webb & Sons of Stourbridge.

To Mr. J. L. Clucas of Ormskirk.

To Messrs. Kent & Brydon of Darlington

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Epicure
Evergood
Great Scot (Immune)
Kerr's Pink (Immune)
King Edward
King George (Immune)
Lochar (Immune)
Majestic (Immune)
May Queen
Ninetyfold
Queen Mary
Sharp's Express
Tinwald Perfection (Immune)
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Arran Rose
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Tinwald Perfection
Lochar
King George V.
Great Scot
Edzell Blue
Arran Chief
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Kitty Glover
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